NOTES ON HISTOLOGY

BY

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PREFACE.

This is a brief outline of the subject of Human Histology simplified and classified in such a way as to make the study of it intelligible and easy for the student.

It is prepared for the classes at the American School of Osteopathy, and is a course of lectures delivered during the term. It is not intended to be exhaustive, but simply contains the essentials arranged in such a manner that the student can easily follow, yet at the same time comprehensive enough to contain the outline of the subject within these few pages.

This edition is characterized by the printing on the one side of the paper only, thus leaving plenty of space for drawings by the student. It is hoped that this new feature will be appreciated, and that the little book will continue to be of service to the student.

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INTRODUCTION.

Histology is the study of the minute structures of the different tissues and organs of the body. *It is also called minute anatomy*, or miscroscopic anatomy, on account of the microscope being necessary for the proper study of these structures or tissues.

Every tissue consists of two parts, (1) the vital cells or corpuscles, (2) the material lying between these cells, the intercellular. On examination of the minute structures of the body, all are found to comply with this rule, and are consequently tissues.

The cells or corpuscles always consist of albuminoid matter, (C. H. O. N. with some P. and S.,) they generally possess a nucleus, and are the only living parts of the tissues. That is, they alone exhibit vital phenomena — nutrition, irritability, and reproduction. The material between the cells, varies in the different varieties of tissue, being in some instances fluid, as blood, lymph, etc., in others solid.

As all tissues develop from the embryonic cell it is necessary to consider somewhat more in detail, the characteristics of cells. A cell consists of a living portion of matter called protoplasm, which usually is enclosed by a membrane or cell-wall, and having within it a spot called the nucleus of the cell. The protoplasm is a fine granular, semi-fluid substance in which coarser granular matter is embedded. It is reticular, being formed by a substance called spongio-plasm, the material between the meshes being called hyalo-plasm.

The protoplasm consists chemically of albuminous principles, along with a proteid-substance plastin. The protoplasm may contain granules of fatty matter, or be vacuolated from globules of watery fluid containing such substances as glycogen in solution. These are either stored for the use of the cell itself, or may undergo some change, leave the cell and serve some useful purpose in the whole organism. A cell-membrane is rarely distinct in animal cells, being formed from the external layer of protoplasm.

The nucleus is oval, spherical, or elongated in shape, and situated in the protoplasm. It has a distinct wall and is composed of fibrils, between

which lie the nuclear matrix. These fibrils are composed of a substance called chromatin, the matrix achromatin; the former staining deeply, the latter slightly. Within these fibrillæ are seen highly refracting bodies called the nucleoli, which stain, with appropriate reagents, different from the nucleus and the protoplasm.

Two other bodies are spoken of, the paranucleus whose function is obscure and the centrosome or pole-corpuscle whose function seems to be associated with reproduction.

The living cell is distinguished by certain phenomena, from those of the inorganic world. These are:

(1) Vegetative — metabolism, growth and reproduction.

(2) Animal — irritability and motion.

Metabolism is the selection and assimilation of the substances adapted for the nutrition and function of the cell. The material either becoming an integral part of the cell, or else after being changed into new substances be retained or given up for use in the body.

Growth is the result of this process of metabolism. The cell may be affected equally producing a uniform enlargement or it may be local. It is the localization of growth that produces specialization of form, e. g., muscle cells, connective tissue cells, etc.

Reproduction may occur in two different ways:

(1) By direct cell division or amitosis.

(2) By indirect cell division, karyo-kinesis or mitosis.

In the former the protoplasm becomes constricted at a point in the cell, and ultimately the portion is set free. This takes place in the simpler forms of reproduction, but it is not now looked upon as the usual mode of reproduction. The second type or indirect division, is the most common. In this condition the nucleus passes through a series of complicated changes, to which the term karyo-kinesis is applied. This change was supposed to be due to the nuclei themselves at one time, now it is supposed to be under the control of — at any rate begun by — the centrosome already referred to. The changes are briefly these. The chromatin becomes increased, forms a thread, which is coiled and twisted in a complicated manner, at first closely packed together then becoming more loosely arranged; the cell-wall and nucleoli disappear, the thread breaks and forms V-shaped loops, at first irregular in position, then more regular with the apex of the V towards the center of the nucleus. The loops then collect in the center and divide at the angle of the V forming a collection of straight rods which now retreat toward the two polar extremities of the

nucleus giving rise to the barrel form. The loops still continue to separate, forming the double star. The protoplasm shows signs of division at the center which results finally in complete separation into two parts or cells. The fibres now go through the same changes as already described, but in the reverse order, reaching ultimately the original form, only having now two cells in place of one. This whole process may take place in half an hour. All the stages may not be complete in a given case, as a passing from one stage to another with the omission of one or more of the stages may take place.

These are vegetative manifestations of vitality. The other two now to be considered are higher and more individual, and for that reason called animal. It is necessary to be careful in regard to the term "animal," it being difficult to draw distinctions between animal and vegetable, seeing that certain plants contain elements possessing irritability, mimosae, etc. The protoplasm in others showing motility in a marked degree.

Irritability. — This is the property by which when external agencies operate changes take place. This is seen in low forms of life. In the higher this is the result of nerve cells, the irritation being from external or internal sources.

Motion is characteristic of all animal cells. It may be manifested where no special appendages are present. This is well seen in the amoeboid movements of the white cells in the blood; although these movements are really changes of form rather than of position. It is best seen where specialization has taken place, as in muscle fibre.

In order to have a complete description of a cell it will be necessary to refer to the changes taking place in the parent cell — the ovum. The ovum undergoes a process of maturing, the essential point being that there is an extrusion of what are known as the "polar bodies," of which there are two. After these pass out a nucleus remains, this is called the female pronucleus. The stage of maturation being complete, fertilization may take place, a male pronucleus being formed, these two nuclei become fused together, then all appearance of nuclei disappears. This is followed by a segmentation nucleus in which the division at first becomes apparent. As a result of this continued division a mass of cells is formed called the blastoderm; this undergoes further division forming a cell area, which divides at first into two, then a third appears, so that there is an outer, middle and inner layer. These are known as the ectoderm, mesoderm and entoderm. It is from these three layers that the different tissues of the body are developed.

All the different structures of the body are for the most part of a complicated nature, yet on examination they are composed of elementary tissues. The elementary tissues of the body are epithelial, connective, muscular and nervous tissues. Of course blood and lymph are to be included among these.

The following is an outline of the several tissues and organs and the different layers from which they are developed:

From the ectoderm — The epithelial structures, principally of the external surfaces of the body, as skin, hair and the epithelial lining of the spinal canal and other structures.

From the mesoderm — Most of the connective structures of the body.

From the entoderm — The epithelium of the internal structures of the body, as of the trachea, digestive tract, urinary bladder and urethra, etc.

Of course we wish it to be understood that this is only an approximate outline, and there are exceptions to it, but approximately it gives the origin of the various tissues of the body.

THE TISSUES — BLOOD.

The blood is a fluid, opaque in color, bright red in the arteries and purplish in the veins. It has a salty taste and peculiar odor, and gives peculiar sensation on handling — clammy. It is alkaline in reaction, this being due to the presence of the alkaline phosphates of K. and Na. The alkalinity is less marked as coagulation takes place. It has a Sp. Gr. of 1050.

Physiologically considered the blood is for the purpose of exchanging materials within the organism. Histologically it must be recognized and grouped among the tissues. It develops from the mesoderm of the embryo. Blood consists of the liquor sanguinis or intercellular material, which is of a pale or yellowish color, and cellular matter or corpuscles. It is usually said that there are two varieties of corpuscles, but in addition to these two — the red and the white — there is the platelet or blood plates, and also coarse white granular corpuscles.

The red corpuscles of all mammals except the camel tribe are circular in shape, non-nucleated and bi-concave. In the camelidae they are oval and non-nucleated. The high shaded appearance of the central portion is due to the fact that they are bi-concave and not to a nucleus being present. The largest red blood corpuscles are found in the amphibians, in which they are oval and nucleated. This same condition of shape and nucleation

is present in all fish — except the cyclostomata, where they are round and discoidal cells — in reptiles and birds.

There are about 5,000,000 red cells in one cubic millimeter of blood of the male and 4,500,000 in the female. The human disc is about 1-3200 of an inch in diameter, and consists of a transparent, colorless stroma and the coloring matter — haemoglobin — uniformly distributed throughout the stroma. When examined in fresh condition they are seen in rouleaux.

The colorless cells or leucocytes are about 1-2500 of an inch in diameter, rather larger than the last variety. They are amoeboid — that is to say, undergoing a continual change, this condition can be well shown on the hot stage of the microscope. The corpuscle is composed of a faintly granular protoplasm, and contains a single nucleus, rarely more than one. Sometimes reticulation is seen on high amplification. Pole corpuscles and attraction spheres have been mentioned also. They go through the stages of karyo-kinesis. Sometimes they contain large coarse granules, these granules are acted on in a peculiar way by Eosin, and are called on that account Eosinophyllic cells. These are the third variety of cells just spoken of.

The other variety, the blood plates, are unstable and prone to disintegration. They are about one-third the size of the red cells. They are known as the corpuscles of Osler. They occur singly but show marked tendency to run together. The granular mass formed by their running together and breaking up, was long known as the granules of Max Schultz. Their function is as yet unknown, but they are supposed to have some relation to the process of coagulation, seeing that they are found so much associated with fibrin. These fibrin strands can be seen very shortly after putting a drop of blood on a slide, if placed in a moist chamber, then corpuscles and broken down platelets are seen in the meshes.

Hayem has some cells called after him, which he thinks have something to do with the production of the red cells. These are small and colored, and are known as the haematoblasts of Hayem. Many observers think them portions of the ordinary red cells.

The blood on coagulation shows peculiar crystals — hæmin crystals.

The color is due to the hæ noglobin and is best seen after adding a few drops of water and letting them wait for some time. On the addition of acetic acid and heating, the rhombic crystals of Teischmann are seen. In medico-legal science it is important seeing this is regarded as the absolute test for blood. If the blood is old and clotted a little NaCl (chloride of sodium) helps.

When certain reagents are allowed to come in contact with blood, they produce different results. In a current of air the red corpuscles lose their shape and become crenated, a salt solution or urine does the same thing. A strong salt solution may cause shrinkage of the white cells. Water causes the red cells to swell and lose their shape — becoming spheroidal —, they lose their color also and become bleached, but are not destroyed as some claim, as is shown by the use of aniline dyes. Water causes the movements of the living blood cell to cease. They swell and on account of their difference in density have an oscillating movement; the so-called Brownian movement. Acids decolorize the red and change their shape to the spherical. The nuclei of the white becomes clear and if mixed with the dye it is stained, showing rings of color.

Brief comparison of the red and white corpuscles:

The red are more numerous; circular; smaller; non-nucleated; heavier than the liquor sanguinis; consist of a stroma or net-work, in which the hæmoglobin is diffused, with no definite cell-wall, originate from colorless cells, from cells like colorless cells in the spleen, and blood glands, from the red marrow of bone, and probably from Luschka's gland and the carotid gland; and their function is to carry oxygen to the tissues.

The white are less numerous; globular; amoeboid; larger; nucleated and granular; lighter than liquor sanguinis; consist of protoplasm, with a definite cell-wall; originate in the spleen, lymphatics; they form red cells; are migratory passing through the walls of the vessels by a process known as diapedesis; they assist in the process of repair, of absorption and play an important part in the role of phagocytosis.

When blood is removed from the living vessels it soon forms a solid mass in a fluid medium. There are three stages in this process, (a) the viscus, (b) the gelatinous, (c) the contraction of the clot and separation of the serum. The first stage is short, usually only a few minutes, prolonged, if cold atmosphere, if large quantity of blood, or if it be in deep vessel. The second stage is also brief. The third may be reached early or else more prolonged. In the process of coagulation the corpuscles usually get entangled in the fibrin. It is owing to this, that the clot has the red color. The clot consists of fibrin in fine fibrils. It is an albuminoid substance. As the fibrin contracts the shrinkage is most marked in the center leaving the surface concave and thus producing the cupped appearance of older writers. The serum in which it floats consists of water principally (90 per cent) and a small quantity of albumen (1-4 per cent) which makes it coagulate on heating; some nitrogenous bodies — creatin,

urea, uric acid, hypo-xanthin; traces of fatty substances and salts consisting of chlorides, sulphates, carbonates of the alkalies and alkaline earths.

Coagulation is due to the formation of fibrin. This is formed as the result of the union of fibrinogen and fibrinoplastine in the presence of a ferment. The fibrinoplastine and ferment are in the white cells, the fibrinogen in the liquor sanguinis.

EPITHELIAL TISSUE.

This is the tissue which covers the different surfaces of the body. It consists of nucleated cells which have at times a definite cell-wall, at others simply a differentiation of the margin. The cells vary in shape on account of the different degrees of pressure to which they are exposed. The intercellular material is very scanty consisting seemingly of a cement substance to keep them together.

The different surfaces of the body may be classified as follows:

(1) The external surface of the body or the cutaneous.

(2) Surfaces immediately communicating with the external — mucous.

(3) Surfaces which do not communicate with the external — serous, e. g., closed cavities, as blood-vessels, pleural surface, pericardial surface.

Epithelium may be considered under the following divisions:

(1) Squamous which is again divided into (a) the simple squamous, which consists of a single layer of cells arranged side by side and presenting an appearance of mosaic structure. It is found in few places in the body, e. g., the tympanic cavity and mastoid cells, the capsule of the malpighian body and the descending limb of Henle's loop in the kidney, the alveoli and infundibula of the lungs, and parts of the ventricles of the brain. (b) Stratified squamous, which consists of several layers of these cells closely approximated to one another. The row of cells nearest the basement membrane is nearly columnar in shape, the cells next become irregularly polyhedral, and those still further distant become more flattened and scaly until the horny layer is reached, when the cell is ready to become separated. In the middle layers of these cells a curious appearance sometimes presents itself. The cells are connected with delicate fibres or threads which show out around these cells like spines and this condition is known as the prickle cell.

(2) Columnar which has also the subdivision, (a) simple, where it occurs as a single layer. It is interesting as a matter of comparison that

this variety is more widely distributed than the simple squamous. The cells are prismatic in shape with granular appearance and irregular surfaces fitting into the corresponding cells on either side. The cells from the intestine have a peculiar striated appearance on the free margin due to the close approximation of a number of rodlets. These, on the addition of certain reagents split up and appear like cilia. In fact they seem as if they were transition forms between the columnar and the ciliated columnar. They are always nucleated and distributed on the walls of the stomach and intestine. (b) Stratified columnar, this variety has more than one layer. It is found in the ducts of certain glands, portion of the male urethra and the conjunctiva palpebrarum. The outermost cells are distinctly columnar, the ends being pointed, forked, or irregularly shaped to fit the deeper and irregularly shaped cells. The nucleus is usually central in the outer layer, but irregular in position in the deeper.

(3) Modified.—There are several varieties of this group. (a) The goblet cell which is a modification of the columnar. They are large in size and clear in appearance, being filled with accumulations of a mucoid secretion, an excess of the normal condition in the columnar cell. These are found in great quantities in the large intestine, some are also present in the small intestine, and are supposed to represent the unicellular gland of certain forms of animal life. (b) The pigment cell where granules of coloring matter are present in the protoplasm, giving rise to special varieties of color, as the color of the dark-skinned races and the color of the retina of the eye. (c) The ciliated cell. There are two varieties of this cell, (1) columnar ciliated, where the main part of the cell is columnar with the ciliated free margin. It is found in the air passages, fallopian tubes, glands of the uterus and several other glands of the body. (2) The spheroidal ciliated where the main portion of the cell is spheroidal. This variety is found — only, some writers claim — in the central canal of the spinal cord and the ventricles, except the fifth, of the brain. Some think also in the tympanum of the ear. These cilia are fine hair-like processes on the free margin of the cell and continuous with the striated margin already described. They are in constant motion during life, sometimes even after the death of the individual. This continued vitality after actual systemic death, is well illustrated in the frog where it continues from one to three days, in the case of the turtle it may continue for several days. Motion is affected by temperature, that of the normal body producing the greatest activity and also by chemical substances, such as, chloroform or ether, producing a paralysis of motion, if carried far

enough absolute death, if not so far the normal activity may be re-established. The function of this condition in man is to carry fluids along towards the outlet, e. g., mucous from the wind pipe and nasal passages, and prevent foreign particles, like dust, from entering. This motion is supposed to be due to the contraction of the cilia themselves, some think assisted by protoplasmic motion affecting the roots of the cilia only, by others due entirely to a rhythmic flow of the hyaloplasm backwards and forwards through these hollow tubes.

(4) Specialized epithelium. Under this classification come (a) the glandular type where the protoplasm of the cell is more or less filled with particles of secretion. The cells are variable in shape, may be either columnar, cubical, polyhedral or spheroidal, and line the walls of the alveoli and ducts of the gland. The watery part of the secretion or excretion of the gland being obtained by a filtration process from the blood; the special substance peculiar to the special gland, e. g., ptyaline in saliva, urea in urine, being formed by the activity of the cells themselves. (b) The special endings of the nerves of the special senses. This is seen in the rod and cone cells of the retina, the olfactory cells, taste cells and the hair cells of the organ of Corti. The term neuro-epithelium is applied to these variations. The cell itself consists of an outer part highly specialized, usually with hairlike processes which receive the stimuli from without, and an inner or central nucleus, the protoplasm of the cell which communicates directly with the nerve fibre.

Epithelium contains no blood vessels, all the nutrition which it has being derived by a process of imbibition from the surrounding parts. This nutrition is conveyed through the delicate clefts or spaces which intervene between the cells. It is a doubtful question whether or not there be any real nerve supply in ordinary epithelium, if present the amount is very scanty. They certainly are present in those regions possessed of great sensibility, like the cornea and the tactile surfaces.

Underneath the epithelial cells there is a modification of the connective tissues to which the term "membrana propria" or basement membrane is applied. This membrane is well supplied with blood and supplies the epithelial cells above it, as above described.

Endothelium.—There is a variety of tissue called endothelium which lines those surfaces which do not communicate with the outer surfaces, in other words lines the serous surfaces. It is derived from the mesodermic layer of the embryo and consequently does not belong to the true epithelial structures. It is in fact of a connective tissue type with characteristics of

epithelium and hence the name applied to it. It is by some however, believed to be simply a simple squamous epithelium with the peculiarity of location in the shut cavities. Some histologists claim that its supposed origin from the mesoderm is not a reality, being derived they think in some way obscured by development among the higher forms of life, from the entoderm. Wherever its actual origin or whatever its proper name, it is just like a simple squamous epithelium, consisting of irregular shaped nucleated cells in a single row with spaces, stigmata and stomata, between the cells.

CONNECTIVE TISSUE.

These are the most widely distributed of all the tissues. They are developed from the mesoderm and are formed by the differences of differentiation and specialization of the intercellular substances. The change in physical characteristics being due to the intercellular matter. In early foetal life the whole structure is a semi-gelatinous tissue, which later on changes to the areolar tissue of the adult. Further, we have the condensation of the intercellular substance and tendon appears, later cartilage and still later bone, the cell remaining practically the same throughout. We recognize several varieties of this group:

(1) MUCOUS which is most immature. The cells are embryonic and communicate with one another by their processes forming a network in there which is a gelatinous intercelluar substance, with sometimes a few wandering cells in it. A typical example of this tissue is found in the jelly of Wharton in the umbilical cord and the vitreous humor of the eye.

(2) RETIFORM OR ADENOID. — This is a modification of the above type. Here there is a fibrillar network of fibrous tissue, in which lie the flattened and nucleated cells. The meshes are usually crowded with leucocytes. It is found in the glands of the body, the lymphatics, the spleen, etc., and is the cause of the peculiar reticulation seen on examining a section of one of these glands by the microscope, and explains the irregularity on the appearance of the space.

(3) WHITE FIBROUS TISSUE. — There are several subdivisions of this variety but in all the intercellular material consists of white fibres chiefly, in different relations to one another. These fibres are fine fibrillae, connected together by some kind of cement substance and are spoken of as connective tissue bundles, these bundles are variable in size and run in different directions. In this way making several varieties of tissue. The fibres are of two varieties, white, which are arranged in bundles and run parallel to one another, and yellow elastic, which are single, coarser, and show a tendency

to curl at their extremities. This fibrous tissue yields gelatin on boiling, and consequently has been called gelatiniferous. The cells of the tissue are of several different varieties. (a) Stellate or fixed connective cells. These are stellar or star-shaped cells, nucleated and sometimes with nucleoli. They are apt to be variable in outline in order to accommodate themselves to their surroundings. (b) The plasma cells, which are soft on account of the vacuolation of the protoplasm, are irregular in shape and found usually in the neighborhood of new forming blood vessels in the new growing tissue. (c) The wandering cells are small, round or ovoid cells, which are capable of change both in position and appearance. They have the characteristics of white blood cells and are supposed to be, in reality, white blood cells in the connective tissue, and for that reason the term hematogeneic cell has been applied to them. (d) The granular or granule cells are spherical in shape with marked granulations of protoplasm, the granules being readily stained by aniline dyes and eosin. They are found in the vicinity of blood vessels also. (e) The pigment cells. These are larger in size, are irregularly branched and show a distinct pigmented granular structure within the protoplasm. They are usually found in the choroid and the iris and in some parts of the pia mater. They are nucleated, the nucleus usually remaining clear. (f) Sometimes also we find fat cells. (See description of fat cells under adipose tissue.)

The different varieties of white fibrous tissue are: (a) Areolar tissue, which is perhaps the most widely distributed of any tissue in the body. It is differently named according to its different locations, e. g., we speak of it as subcutaneous, when referring to that underneath the skin; investing, when to that surrounding organs; supporting, protective or parenchymal when it is within the organs supporting vessels. The fibrous portions are distributed irregularly, forming meshes of lesser or greater dimensions, so that we have a loose or spongy type of tissue. All the different varieties of cells referred to above are present. (b) Fascia. The fibres of this variety run closely associated but irregularly and form a dense sheet of fibrous tissue. (c) Aponeurosis. This is a firm sheet of fibrous tissue with the fibres running either parallel to one another or irregularly. There is an aponeurosis of investment, a tough membrane surrounding muscles and an aponeurosis of insertion by which the muscles are inserted or attached to the bone. Aponeurosis is simply a flattened tendon. (d) Ligament. Is a white fibrous tissue, the fibres closely packed together forming very strong bands, which connect the bones together at the joints. When torn it forms two irregular surfaces. (e) Tendon, as referred to above, consists of quantities of white

fibres running in bundles parallel to one another. The cells are of the stellate variety, situated in the tissue in chains or rows; they are flattened on account of the pressure to which they are subjected, and have what is spoken of as a keel, which fits into the neighboring bundles or fibres, in this way keeping the cells in position. These cells are sometimes spoken of as the quadrate cells of Ranvier.

Vessels and nerves. Arteries, veins, nerves and lymphatics pass freely through the areolar tissue, but only a small amount of blood capillaries. In some locations, however, for example, the subcutaneous structures, many lymphatics and capillaries are present. The nerve distribution is very uncertain, probably absent. In the other varieties of white fibrous tissue where more fibrous structure is present, as in ligament or tendon, the vessels pass between the bundles and communicate with one another by branches forming more or less open networks. The lymphatics are present in more or less abundance, sometimes forming clefts. Nerves are also present in some cases at least running between the fibres.

(4) Adipose Tissue. — This consists of vesicles or cells clustered together with a small amount of intercellular tissue between them. It is really a loose variety of areolar tissue in which the connective tissue cell has lost its characteristic appearance and the whole cell-mass becomes an oil globule. Each cell or globule consists of a cell wall, a nucleus in the cell wall and the oil globule forming the mass of the cell, with sometimes crystals in the center of the oil globule. These crystals are usually crystals of margarine. The development of these cells shows that they are really connective tissue cells which become modified by the change into oil globules. In early foetal life the areolar variety of connective tissue can be seen undergoing a process of transition, at first small drops of oil make their appearance in the cells, later replacing the whole of the cell structure. It is found in almost every part of the body, there being a few places which are absolutely exempted, e. g., the subcutaneous tissue of the eyelids and penis, within the cranium and in the substance of the lungs. Adipose tissue plays several important parts in the organism, thus indicating that it is not a degeneration tissue, as is claimed by some, but really a fully developed normal structure. The most important functions which it performs may be included under these three subdivisions: (1) protection; (2) warmth; (3) storage of nutrition. It is well supplied with blood and lymphatics, the clusters of fat cells being closely approximated to a smaller vessel and in this way is closely associated with absorption and nutrition. No nerves are present in the tissue save those fibres which pass through the structure.

(5) Yellow Elastic Tissue. — This variety of tissue is possessed of great elasticity and resiliency. It is found in different parts of the body and is an important element in the structure known as the ligamentum nuchae, which possesses the characteristic of strength and at the same time is fairly small in amount and by its elasticity allows considerable motion, with the absence of redundancy. It is usually spoken of as existing in two forms or varieties: first, existing as fibres in the ligamentum nuchae, in the subcutaneous tissue, pleural surface of the lungs, the cryco-thyroid membrane and in the true vocal cords, secondly, as a sheet or membrane in the walls of the arteries being proportionally more abundant in the larger arteries. In the inner coat of these arteries it forms a thin homogeneous membrane with a number of spaces or perforations and is known in this position as the fenestrated membrane of Henle.

(6) Cartilage. — Many histologists in speaking of cartilage speak of it as being a tissue by itself. Cartilage, however, is simply a variety of connective tissue and ought so to be considered. Cartilage is the first of the groups of connective tissues which have a hardness or firmness in structure, and this is due mainly to the relation that the cells bear to the intercellular. The cartilage cell is a nucleated cell, unbranching, with sometimes a nucleolus and a distinct limiting membrane. There are several varieties of cartilage: (a) True or hyaline cartilage, the matrix of which is usually spoken of as being wholly chondriniferous. We distinguish between two varieties of this group: (1) temporary cartilage and (2) permanent cartilage. This cartilage is seen in two different positions in the body and is spoken of accordingly as being costal cartilage or articular cartilage. The former is of a pale yellowish color, very firm and flexible but readily broken if bent too far, and on section shows a hyaline matrix with true nucleated cartilage cells. The matrix is clear, homogeneous, slightly granular and round a single cell or group of cells a layer of a firmer nature presents itself which is spoken of as a capsule within which the cells lie. It is simply a differentiation in the protoplasm. In growing cartilage the cells are firm, in different states of division and towards the surface are flattened, as if by the pressure of the perichondrium. This latter is a fibrous membrane which surrounds the cartilage and carries the blood vessels for the nutrition of the cartilage, as no blood vessels are present in the cartilage itself. The articular variety is found on the surface of bone at the points where they come together and form joints. It has a somewhat granular matrix and the cells lie usually in vertical rows. In the deeper parts these cells are characteristic being in rows, but towards

the surface they become more irregular and flattened. It is somewhat interesting that in these varieties of cartilage, chemical reagents separate the matrix into strands and in this way shows the relation to the true connective tissue. In addition to that, chemical analysis shows that mucin is present, indicating that a cement substance is present also in the structure. Articular cartilage has no perichondrium but receives its nutrition from the blood vessels below.

(b) CALCIFIED. — This is found on the surface of bone and between the articular cartilage and true bone. The matrix consists of mineral matter and differs only from bone in having no canaliculi.

(c) ELASTIC OR YELLOW CARTILAGE. — This variety resembles hyaline cartilage but is distinguished by the fibres of a finer or coarser nature, lying in the matrix. These elastic fibres originate by a transformation of the matrix. It is tougher and more flexible than ordinary cartilage. It occurs in the epiglottis, the external ear and the eustachian tube. In early life the epiglottis consists of hyaline cartilage but becomes gradually converted into this elastic variety as the years advance. In some cases the hyaline condition does not entirely disappear so that there are areas of hyaline cartilage remaining in the adult elastic condition. The cartilage cells lie in the spaces between the elastic fibres.

(d) WHITE FIBRO-CARTILAGE. — This variety consists of bundles of white fibrous connective tissue extending in different directions and having amongst them the cartilage cells. These cells occur in groups, have a thick capsule, are usually arranged in rows and are comparatively few in number. It is found in the intervertebral discs, the symphisis pubes, in the inferior maxillary articulation and in the semi-lunar cartilages of the knee joint.

7. BONE. — This variety of connective tissue has a matrix of mineral matter characterized by hardness and elasticity and having nucleated cells. These cells differ from cartilage cells in that they have many branches. These cells lie in spaces or lacunae and their branches in narrower spaces or canaliculi. The matrix consists of organic and inorganic substances united in such a way that either one may be removed without destroying the other. The inorganic, forms about two-thirds of the matrix and consists chiefly of the phosphate and carbonate of lime and a small quantity of the chloride of sodium and salts of magnesium. It is obtained by burning the bone, in this way destroying the organic part. The animal part of the matrix consists of fine fibres arranged in laminae or plates kept together by perforating fibres. This is obtained by treating the bone with hydrochloric

acid in this way removing the mineral matter. It forms the other third of the matrix and renders the bone tough and elastic.

There are two varieties of bone. (a) Spongy or cancellous bone which consists of fine spicules and thin lamellae arranged irregularly and forming a network, the spaces being filled with vascular connective tissue. It is found in the ends of the long bones, the inside of the short bones and in such bones as the skull which have two plates, in the space between these two plates — this space is termed the diploe. (b) Compact or dense bone. In this variety the laminae are closely approximated to one another, this solid or compact condition being the result of the regularity of the plates and their close relation to one another. These plates are laid down in such a way as to form rings with a central space or canal. This canal is spoken of as a Haversian canal. They are small, of irregular size ranging from the one two-thousandth to the one two-hundredth of an inch in diameter. The larger are towards the center and the smaller towards the circumference, communicating in either case with the surface. They run in a longitudinal direction in reference to the bone but communicate with one another, those towards the circumference opening on the external surface, and those toward the center opening on the internal or medullary surface of the bone. They each contain one small artery, one small vein, nerve fibres, lymphatic vessels and some connective tissue, the smaller ones may contain capillaries only.

On making a cross-section through the long bone, it is seen to consist of numerous areas arranged in rings. Each of these rings with its central opening being a Haversian system and the masses of rings with their openings being the solid or compact bone. Each Haversian system consists of a central opening or canal; concentric plates of bone around the canal; numerous irregular spaces or lacunae between the plates, within which lie the bone cells, and narrow radiating lines or canaliculi running from the lacunae, within which lie the branches of the cell. On careful examination irregular Haversian systems are seen to fill up the spaces between the regular systems. These differ only from the complete systems in that the process of absorption has taken place to such an extent only as to accommodate the complete systems.

The outer surface of bone is covered with a dense membrane of white fibrous tissue, except where the articular cartilage comes in contact with the bone. This is the periosteum and corresponds to the same structure which surrounds cartilage known as perichondrum. It is from the periosteum that bone receives its nutrition, partly on account of the blood-

vessels it contains, as well as the fact that on the surface next the bone it is very cellular, and on this account, new bone originates from it. This part of the periosteum is spoken of as the osteogenetic layer, because of its giving origin to bone. The periosteum consists mainly of white fibrous tissue with some yellow elastic fibres. Lymphatics and nerves are present also in the periosteum.

The central canal of the bone has also a covering of fibrous tissue, it differs only from the periosteum in being more delicate, it is called the endosteum. It receives its nourishment form the nutrient artery.

There are two different varieties of marrow in connection with bone, (a) yellow colored marrow found in large cavities, e. g., the shafts of long bones, it consists largely of adipose tissue. (b) Red marrow in the cancellous bones. It consists of areolar tissue which is extremely cellular. These cells are of different varieties, the true marrow cell being round, amoeboid and nucleated, resembling the large white blood cell. Among these cells are some of a smaller size, reddish color but also nucleated and amoeboid. They resemble the colored nucleated blood cell of the embryo. The adult blood cell is supposed by many to be developed from these cells and they are accordingly spoken of as erythroblasts. Still another variety of cell is found, especially where absorption of bone is taking place, but not necessarily so. They are large and usually multinucleated, sometimes with a very large single nucleus. Further than that an additional cell is spoken of, which contains blood cells undergoing transformation into pigment, like those in the spleen. Marrow is extremely vascular, the vessels having thin walls, some doubt whether the capillaries have a complete limiting wall.

Bone is formed by a process which is spoken of as ossification. Ossification takes place in two different ways. (a) Ossification in membrane. This is seen in the flat bones, as the flatbones of the skull. The membrane is of a fibrous tissue structure of an embryonic character, which is exceedingly cellular and vascular. The fibres become inclosed in a calcareous matrix which extends further and further forming spicules of bone with spaces between in which are osteoblasts surrounding the blood vessels. This process begins towards the center and extends towards the periphery, until the whole membrane has become ossified and the adjacent bones become united by the serrated suture. (b) Ossification in cartilage. In this variety of ossification the bone is pre-formed in cartilage, that is to say, the shape and outline of the bone have already appeared in the original cartilaginous structure. This is the more common method and is well

seen in the case of the long bones where several small centers of ossification appear in the shaft, somewhat later similar centers appear in the ends. By the extension of the former centers the shaft is formed, by the extension of the latter the ends are formed. Growth in the length of the bone taking place in the plate of the cartilage which lies between the end or epiphysis and the shaft or diaphysis, the plate of cartilage being spoken of as the epiphyseal cartilage. These centers of ossification are simply spots or areas where calcareous particles are deposited in the cartilaginous matrix. The whole process of ossification may conveniently be divided into three stages. (a) The cells in the middle of the cartilage become enlarged and arranged in rows with calcareous particles in the matrix. The cells underneath the periosteum deposit fibrous plates which become calcified containing some osteoblasts in their substance. (b) Some of this sub-periosteal tissue makes its way into the center of the cartilage and as it does so forms spaces containing osteoblasts and blood vessels. (c.) Ossification advances towards the extremities of the cartilage, and deposition of fresh bony plates takes place in the spaces and under the periosteum. These spaces are separated from one another by rows of cartilage which become gradually absorbed, as the process of ossification goes on, by large multi-nucleated cells which are spoken of as osteoclasts. They are of the same nature as the large multi-nucleated marrow cell and are always present where absorption of bone is taking place.

In regard to the origin of these cells there is some doubt in the minds of histologists whether they originate entirely from the periosteum as described, or whether they may be derived in some way from the cartilage cells. The bone which is at first laid down is irregular, with large spaces, the result of absorption; these spaces are separated from one another by spicules of bone and if this condition continues to exist permanently we have the cancellous type of bone. If the bony plates are laid down regularly in rings around the blood vessels we have the compact type of bone, the only difference between the two forms of bone consisting in the regularity or irregularity of the deposition of the plates of bone.

MUSCULAR TISSUE.

It is owing to the action of the muscular tissue that we have motion in the different parts of the body. These muscular masses or bundles consist of smaller bundles which again become divided into the minute fibre. Muscular tissue has a peculiarity that it is contractile. This contractility is present in all forms of living cells, being peculiar to the condition we

speak of as life. The only peculiarity, so far as the muscle is concerned, is this, that the muscle fibre has a limited contractility, the limitation being confined to a single direction. Sometimes muscle fibres are distributed in sheets and not in masses as we have them in "muscle;" this is seen in the walls of the intestines and in the coats of the hollow viscera. We have two varieties of muscular tissue, these varieties depending on the fact that the one group acts under the direct control of the will, the other without the will. Hence we have the two terms voluntary and involuntary. It is necessary to bear in mind the fact that although voluntary muscles act under the control of the will, yet some of them very frequently, and all of them at times, act in obedience to a stimulus. Still we take this division as our basis for the consideration of the properties and characteristics of muscle fibre. It is necessary to know the particular variety of muscle fibre we speak of, seeing that the muscular fibres in the different forms of animal life, are not similar. Our references are to the form of muscular fibre in the human being and higher forms of animal life.

VOLUNTARY MUSCLES. — In the variety of muscle we speak of as voluntary the ultimate fibre runs in relation to its neighbor longitudinally and the fibres do not intertwine. Usually these fibres extend from the one end of the muscle to the other. Each fibre is about 1-400 part of an inch in diameter, and variable in length. These fibres as a rule extend from one end of the muscle to the other but some cases exist where this condition is not present, e. g., the rectus abdominalis which has tendinous intersections, and the tibialis posticus which has a tendinous margin, the muscle fibre extending in an oblique direction between the margins. In these cases there is much less length of contraction but there is greater force in the shorter contraction. These fibres are grouped together in small bundles or fasciculi, masses of these fasciculi forming the muscle. Around the circumference of the muscle there is a sheath which consists of areolar tissue and the term epimysium has been applied to this sheath.

In addition to the outer sheath which surrounds the muscle itself, we have prolongations of this same tissue extending inwards and forming a sheath to the fasciculus which is called the perimysium. Extension of the same structure further between the individual fibres is spoken of as the endomysium. This latter has no elastic fibre in its structure, the two former have. The function of this endomysium is to support the blood vessels and nerves in their course between the fibres and at the same time bind the fibres together. There is not a complete sheath of endomysium, that not being

necessary, seeing there is a perfect sheath to the muscle fibre in addition. These individual fibres differ in their appearance, that is to say one fibre may be considerably coarser than another. It is true, usually, that small muscles, e. g., the muscles of the eye have fine fibres, the large muscles, e. g., the glutei muscles have coarse fibres ; yet this is not a definite rule. The muscle fibre in a small body, for example the female, is much finer as a rule than the muscles of the larger body. The most of the muscle fibres run parallel to one another, but there is an exception to this rule in the muscles of the tongue, which sometimes are branched. It has been shown by Kolliker that this condition is characteristic of the muscle of the frog. Huxley states that it is frequent in the facial muscles of some mammals. The sheath of the muscle fibre consists of a very fine homogeneous elastic structure. It shows distinctly where the muscle fibre has been ruptured and is well marked among amphibians and fish where it is stronger and thicker. Between the muscle fibre and the sheath lie numerous cells, these are the muscle cells or muscle corpuscles and are characteristic in this form of muscle lying always between the sheath and the fibre. They are oval in shape, clear in appearance, with granular substances at either end supposed to be the representation of a disappearing cell. Usually speaking these cells have two nuclei brought out distinctly on the addition of an acid. These cells in some forms of animal life, e. g., the frog, lie in the substance of the muscle fibre.

The muscle substance proper shows a peculiarity always referred to as striated. This striation is transverse, is not merely superficial but extends entirely through the whole of the muscle substance. These striæ are closely approximated to one another, about 17,000 being present as a rule to the inch of fibre. This number may be much increased, in fact it is claimed by some, that there may be 34,000. This condition of striation or non-striation was and sometimes is still taken as the basis of comparison between muscle fibres. It is not a correct comparison, because all varieties of muscle in these higher forms of life have striation more or less marked. On focusing carefully this striation is represented by a dark and clear line, each of these lines being intercepted by another line. The line running through the clear band is known as Dobie's line or Krause's membrane. The one running through the dark line is known as Hensen's line. In addition to this transverse striation a longitudinal striation is also present, and corresponding with this transverse formation of discs we have a separation longitudinally at these striations into columns or sarcostyles; these sarcostyles are united with one another by a substance

called sarcoplasm. There are different opinions held in regard to this striation, some considering that the muscle fibre is composed of tiers of these discs. Each of these discs consists of the following parts:

(1) Clear Area — The lateral disc of Engleman.
(2) Dark Area — The sarcous element of Bowman.
(3) The Clear Line through this disc — Median disc of Hensen.
(4) Another clear area — Lateral disc of Engleman.

Each of these discs is called a sarcomere. This theory is not now received generally. These appearances are distinctly seen in the fibre, but they are regarded now as optical expressions of substances in layers acting differently to light. Another fact is that the fibres in life during contraction and relaxation present different optical appearances. When polarized light is used, it is found that the dark area has a light refraction, the light area a dark refraction. The more modern idea of Schafer that the muscle substance consists of rod-like structures, seems to present a more reasonable view of the condition. Whether it be as is claimed by Marshall, that the rods are the representation of a fibrillar net work, the rest being filled with fluid, has not yet been decided. It would be interesting, and at the same time reasonable, if we could establish the fact of the presence of this fibrillar net work. In this way the muscle fibre could be placed under the category of the true animal cells. The muscle fibre develops from the mesodermic layer by elongation of cells and the development of nuclei, the striation appearing later. Later muscle develops by longitudinal division of the older fibres.

Blood vessels are abundant, the arteries and veins entering the muscles dividing and subdividing as they pass between the fibres ultimately ending in the smaller capillaries which pass between the individual fibres. Those muscles which undergo the greatest activity have the greatest supply of blood, e. g , the diaphragm. Lymphatics are present only in the connective tissue between the fibres. Nerves are present and of considerable size. The branches of these nerves form plexuses from which small fibres arise and end in the muscle fibre. Sometimes these nerve fibres lose their sheath and form " motor end plates."

Involuntary Muscles. — The typical example of this variety is found in the intestinal walls. These consist of fusiform cells arranged irregularly and forming bundles. The cells are about 1-600 of an inch in length, sometimes prismatic on section, sometimes flattened and some of the cells being bifurcated. These cells are striated in a longitudinal direction and have a central nucleus. The nucleus is oval and sometimes

contains nucleoli. They develop from nucleated cells in the embryo undergoing elongation, the ends becoming pointed, the nucleus also becoming pointed. It has been found that increase takes place both by elongation and thickening of old fibre cells and it is through the development of granular cells lying in the tissue in the gravid uterus that physiological growth is established, decrease taking place afterwards by shrinking and absorption.

CARDIAC MUSCLE. — These fibres are different from those already described. The cells are quadrangular in shape, some of them with branching extremities, always striated, with a nucleus in the substance of the cell, and without any muscle sheath. A microscopic examination of this variety of muscle is sometimes obscured by the granular appearance of the section, the result of the irregular distribution of the cells in relation to one another and consequently the cutting of the fibres in an irregular manner. It is necessary to use some reagent like nitrate of silver to bring out the division into cells.

Cardiac muscle is well supplied with blood and differs from the voluntary in its great supply of lymphatics. The muscular fibres are just like a sponge with the lymphatics between. The nerves are arranged into plexuses and are non-medullated at their termination in the muscle. Beneath the lining membrane of the ventricle a beaded appearance visible to the naked eye is present spoken of as Purkinje's net work. These consist of quadrangular cells with one or two nuclei. At the margin transverse striae can be seen in the cells joining with their neighbors in such a way as to form a net work of fibres with cells in the meshes. It is probable that these cells have been arrested in the growth and have continued to grow irrespective of striation.

NERVOUS TISSUE.

We have in the body two distinct nervous systems, (a) the cerebrospinal which consists of the brain, the spinal cord, the spinal nerves, and the cranial nerves. (b) The sympathetic which consists of small centers and the fibres associated with them. The sympathetic system consists chiefly of the ganglia arranged in a chain on either side of the vertebral column and connected with the fibres. It is chiefly related with the viscera and blood vessels.

Nervous tissue in an embryonic condition are composed entirely of cells, they are spherical in shape and known as neuroblasts. As growth takes place they become elongated and from the narrow end a delicate process

extends, this is termed the axis-cylinder process. From the margin of the cell other processes arise, which are not so long, these are spoken of as ramifying processes or dendrites. The cell with the above processes is termed the neuron, if there be any secondary branches it is spoken of as neuro-dendron.

Each of the nervous systems consists of three parts: (a) Nerve center: — Each nerve center consists of nerve cells and a delicate connective tissue of neuroglia binding the cells together. Each of the nerve cells contains a nucleus, and is composed of granular or striated protoplasm which at times contains pigment. They have no cell-wall. There are several varieties of cells, they are distinguished from one another by the processes which come off from them. Cells having one process are spoken of as uni-polar, these are mostly found in the lower forms of animal life, e. g., in connection with the sympathetic nerves of the frog, and in the olfactory mucous membrane. The bi-polar have two processes which may come off either in opposite directions or close together, in this way there may be quite a difference in the appearance of the cell. They are found in the ganglia of the spinal cord. The tri-polar or as they are called pyramidal on account of their shape, are present in the grey matter on the surface of the cerebral hemispheres. The multipolar cells have many processes, and are found in the gray matter of the spinal cord. There is a variety of cells in the cortical area of the cerebellum which are flask shaped and because they resemble the tadpole are called tadpole cells. They are frequently spoken of as the cells of Purkinje. Apolar cells, that is cells without any process, are sometimes found, but they are probably either mutilated cells, or are immature or artificial. These processes are of two different kinds corresponding to the description above, in the one the axis-cylinder process, the other irregular branched protoplasmic processes which undergo dichotomous division and terminate in fine networks. This is illustrated by the multipolar cell and still better by the cells of Purkinje. In the first variety the axis-cylinder is continued directly as the axis-cylinder of the nerve fibre, in the latter the axis-cylinder remains short and rapidly undergoes division, rapidly forming an arborescent network in the neighborhood of the cell, sometimes encircling other cells. If this network entirely surround the cell it represents the cell described by Purkinje and which we have already referred to. We have thus two different varieties of cells depending on the characteristics of the processes, the one leaving the nerve center and forming the center of the nerve fibre, the other remaining in the nerve center and encircling the adjacent cells.

The cells are bound together by a variety of tissues which is considered by some to be of the retiform type of connective tissue, but the term neuroglia has been applied to it by Virchow. It consists of cells and fibres arranged irregularly and serving as a matrix in which the nerve cells lie. The cells are flat and branching, the branches passing between the nerve cells, which they aid in supporting. The term has been applied to it because the cells are spider-like and lie in the nerve structure.

These nerve centers or ganglia have a sheath which is quite distinct from a cell wall, being a continuation of the sheath of the nerve fibres with which they are connected. The sheath is nucleated.

(b) Nerve Fibres. — The sheath is the basis of a distinction between these fibres, one variety having a sheath, the other having none. In the medullated or white fibres we have this medullary sheath surrounding the axis cylinder. This medullary substance, or as it is often called, the white substance of Schwann, is semi-fluid, somewhat of a fatty nature, highly refractive and giving a tubular appearance to the nerve fibre. It is almost continuous throughout the length of the fibre, except in the peripheral fibres, where it is interrupted at regular intervals, these interruptions being the nodes of Ranvier, the spaces between the interruptions being the internodes. In addition to these nodes there are oblique lines in this substance dividing it into irregular parts, the so-called medullary segments. Some think these lines are artificial, seeing they only become apparent when it is stained; they are probably normal, only brought out by the stain. When stained the fibre appears as if it had a double edge, hence the term "double-bordered" applied to this variety of nerve fibre. The axis-cylinder is a fine, soft thread extending throughout the length of the nerve. It is composed of fine fibrils, and has consequently a longitudinal striation. It is supposed by some to have a very fine sheath. At the nodes there are enlargements of the axis-cylinder, some think an accumulation of the material — neuroplasm — between the fine fibrils. Each of these fibres has a sheath or neurolemma outside of the medullary sheath, so long as they are without the central nervous system; within the central nervous system they are devoid of neurolemma. The non-medullated fibres are sometimes found mixed with the medullated, but are mostly in the sympathetic system.

They are pale in color, are beset with nuclei, probably indicating a delicate sheath; in fact some of the fibres in the sympathetic have a sheath. The fibre consists of the axis-cylinder, sometimes with a sheath or neurolemma, but most frequently without it. The fibre without the

sheath is found only in limited areas of the cerebro-spinal nerves; those without the sheath are in the olfactory nerves and most of the sympathetic nerves. They branch frequently throughout their length, which the medullated never do unless at their termination.

The nerve fibres are usually gathered into cords or trunks. These trunks have a sheath of connective tissue, which is called the epineurium. The trunk is composed of several funiculi or bundles of nerve fibres, each funiculus having a sheath or perineurium, which has two distinct surfaces. The individual fibre has a sheath also, or endoneurium, which supports the blood vessels and lymphatics. The epineurium receives small nerve fibres just like any other structure, spoken of as the nervi nervorum.

(c) Nerve Terminations. — We have to consider the termination of sensory and also of motor nerve fibres. In the sensory variety we have either special endings or else free terminal ramifications. Where the fibre is passing to its ultimate termination the white substance or medullary sheath abruptly ceases at a node of Ranvier; the fibre then continues as the axis-cylinder with its neurolemma. This latter also soon disappears, leaving the axis-cylinder, which has already become very fine on account of the repeated divisions. Even these small fibrils continue to divide until the fine ramifications form the plexus, which is distributed in the skin and mucous membranes. Such are the ordinary terminations. The special terminations are more complicated. They are usually classified under three divisions: (1) Tactile cells. These are found in connection with the eipdermis. If simple, they are oval in shape, but if compound, as they sometimes are, they are spherical. They consist of a connective tissue sheath, which is simply an enlargement of the sheath of the nerve fibre and still continuous with it. The axis-cylinder is surrounded by the medullary substance for a short distance, but soon looses it. The axis-cylinder then undergoes division into fibrillæ, which are distributed throughout the cell. (2) End bulbs. These are found in the conjunctiva of the eye, the mucous membrane of the lips and tongue, the outer covering of the nerve trunks, and with some modification in the integument over the external genital organs, sometimes in the neighborhood of the joints. The bulb consists of an outer covering or capsule, which is a continuation of the nerve sheath, composed of connective tissue, with well marked nuclei; an inner granular or striated protoplasmic mass, within which lies the termination of the nerve fibre, with somewhat of a nodule at the extreme end, the medullary sheath ceasing at the entrance into the

bulb. (3) Pacinian corpuscles. These are larger and more complex than either of the others just mentioned. The body of the corpuscle is composed of connective tissue, arranged in layers somewhat after the fashion of the layers of an onion. Within this thick sheath there lies a single nerve fibre, surrounded by the medullary sheath and within a small central bulb which seems to be an enlarged endoneurium. After the nerve passes well up through the corpuscle it sub-divides and terminates in an arborescence.

In regard to the terminations of the motor nerves we have to consider modifications in varieties of plexuses. In the involuntary muscle the fibres are non-medullated and enclosed by a thin perineurium. The fibres are arranged in small bundles and form plexuses with many ganglion cells. From these plexuses other fine fibres pass off, which form secondary plexuses from which finer fibres pass to the muscle fibre, ending ultimately in free ends, which may be either pointed or thickened. In the voluntary muscle the medullated fibres terminate in special motor-plates or end-organs. When the nerve fibre reaches the muscular fibre the neurolemma becomes continuous with the sarcolemma, the medullary sheath terminates and the axis-cylinder ends as a fine arborescence, which is embedded in a mass of granular nucleated protoplasm. Each muscle fibre has a single end-plate, but occasionally there may be two or even more.

In the voluntary there are some non-medullated nerves also. These are arranged in a fine net work between the muscle fibres.

Tendons have a special modification of terminal plexus. The plexus appears as an elongated mass near the junction of the muscle and the tendon. It is distributed over the tendon fibre, enters between the fibres and terminates in an arborescence. These are non-medullated nerve fibres. There are in addition to these several medullated nerve fibres in connection with the tendon.

The special terminations of the nerves of the special senses depend upon the highly differentiated neuro-epithelium. This neuro-epithelium acts as the receiver of the stimuli from without, the nerve fibres transmitting these impressions. Whether there be an accurate continuity between the epithelium and the nerve fibre has not been absolutely decided, but that there is a close connection seems apparent.

The Digestive Tract.

The Teeth. — Teeth consist essentially of three mineralized substances arranged so as to form a solid structure with a hollow space in the

center. This space is filled up with the pulp which is soft, vascular and sensitive.

The greater part of the tooth is made up of dentine, a substance somewhat allied to bone but differing from it in having neither Haversian systems nor lacunae. Canaliculi or dentinal tubules are present. These are very small channels communicating with one another by finer channels, they are lined by a dentinal sheath and are filled up by prolongations of the pulp forming the so-called dentinal fibres. Beneath the crusta petrosa there is a layer of Purkinje, the granular layer or the interglobular spaces which are filled up with a soft substance.

The enamel covers that portion of the tooth above the level of the jaw and is very much more dense than dentine. It is composed of hexagonal elongated prisms lying close together and held in this position by a small amount of cement substance. There is a somewhat indistinct striation apparent, on making a close examination, due to a fairly regular marking upon the individual prism. There is a somewhat dense membrane covering the outer surface of the enamel, the enamel cuticle or the membrane of Nasmyth.

The crusta petrosa or cement bears the same relation to that portion of the dentine embedded in the jaw that the enamel does to that portion of the dentine which is above the jaw; in other words this crusta petrosa covers the part of the tooth embedded in the jaw. It is very similar to bone in structure except that it has no Haversian canals, it is claimed by some that these canals are present in the adult condition, if not always, at least frequently. There is a strong fibrous membrane — the dental periosteum — covering the fang and also reflected to line the alveolus in this way fixing the tooth into the socket.

Development of Teeth. — About the end of the second month of intra-uterine life a longitudinal thickening or fold of epithelium takes place into the tissue underneath — the enamel germ — following this lateral, flask-shaped masses of cells appear, corresponding in number to the temporary set of teeth, at the same time a similar number of papillae from the connective tissue structures appear and develop in such a way that they cover the flask-shaped bodies — the dental bulbs — all of which are cut off from the epithelium of the mouth and enclosed in a sac, each of the bulbs becoming an enamel organ. The function of the enamel organ is to give shape to the tooth and later form enamel, which it does only over that portion of the tooth spoken of as the crown. The dentine is formed by a calcification of the outer part of the papillae, the inner re-

maining uncalcified and forming the pulp. The permanent teeth are formed by the separation of a small portion of the enamel germ of the milk tooth which goes through the stages referred to and ultimately takes the place of the milk tooth after its irruption. The remaining six teeth in each jaw, which have no representative in the temporary set, are formed by the growth of special enamel germs from the original epithelial thickening which extended backwards, and the changes which these growths undergo resulting in the formation of the permanent tooth.

THE TONGUE. — The tissues of which this organ are composed are many. We have the greatest part of it made up of muscular fibres, of the striated type running in different directions and forming a very beautiful network. They run chiefly in a longitudinal, transverse, or vertical direction and are divided into two equal, lateral, parts by the membranous septum which almost separates the tongue into two. In addition to the muscular tissue there are adenoid, connective, and adipose tissues, as well as the epithelium and the tissues associated with the outer covering of the tongue.

The dorsum of the tongue is covered by an epithelium in which lie many small papillae. These are of three different varieties, (1) conical or filiform, which are small cylinders with sometimes smaller fibrillae or filaments extending from their apices. They are irregularly distributed over the entire dorsum of the tongue. (2) Fungiform or fungoid papillae, they are somewhat rounded in shape, with a tendency towards the formation of a neck so that they resemble a fungus. The surface of these papillae is covered with smaller or secondary papillae. They are distributed among the conical and are not so numerous as the conical. (3) Towards the back of the tongue arranged like a letter V are another kind, the circumvallate papillae. They resemble the latter in appearance only they are surrounded by a hollow space and consequently have received the name, seeing there is a space running around the papillae. Usually there are about ten or fifteen of these papillae arranged in that way on the tongue. In the sides of the papillae and also the sides of the fossae are several small bodies the so-called taste buds or gustatory organs. These papillae are made up of connective tissue, some elastic fibres and the layer of stratified squamous epithelium which covers them. The epithelium on the conical variety is thicker and somewhat cornified.

The gustatory organs or taste buds are, as already indicated, found in relation to the circumvallate papillae but are found also on the under surface of the soft palate, the epiglottis and the sides of the tongue, some-

times irregularly in the mucous membrane of the mouth or tongue. They consist of aggregations of epithelial cells situated in the stratified epithelium with their base in contact with the corium and in direct communication with the terminal fibres of the glosso-pharyngeal nerve. They are really modified terminations of nerve fibres.

The apex, of the mass of cells forming the taste bud, is narrow and opens through the epithelium by the gustatory pore which is simply an opening in the epithelium for the taste bud. The bud itself consists of cells which are of two different varieties, (a) the gustatory which are fusiform in shape, nucleated and bi-polar. The distal pole or process is very fine and terminates in a delicate cilium-like appendage projecting through the pore just referred to, the proximal pole branches and is connected with the nerve fibre. (b) The sustentacular or supportive, these are narrow and elongated lying between the gustatory.

At the back part of the tongue are well marked openings or crypts, in the walls of which are well defined masses of adenoid tissue forming what are spoken of as the lymph follicles of the tongue, from which at times wandering cells escape and making their way into the mouth are met with there as the mucous or salivary corpuscles.

There are two kinds of glands in the tongue, (a) the mucous which secrete a muciniferous fluid, hence the name, situated along the edges and at the root, their ducts often opening into the crypts already referred to. They consist of a basement membrane upon which are the glandular epithelial cells, those of the duct being flattened and sometimes ciliated. (b) The serous which secrete a thin watery fluid containing albumen, they are situated close to the circumvallate papillae, their ducts opening between the papillae and the wall. These also consist of a fine basement membrane upon which are the short granular cells.

The tongue has a good supply of blood, the vessels being so distributed as to reach the papillae and form networks around the glands. The lymphatics are also well distributed so that a superficial set carry from the papillae and a deeper set does the rest. The nerves to the tongue are the glosso-pharyngeal and the lingual branch of the fifth.

The Salivary Glands. — We have three of these situated in relation to the mouth as the name applied to them indicates. It happens that these three glands represent three separate divisions or varieties of glands, divisions more characteristic in the lower forms of animal life than in the human. There is (a) a mucous salivary gland represented by the sublingual in the human. It is a compound tubular gland the structure of the

tubule being the membrana propria and upon it the columnar epithelial cells, the duct is composed of an outer fibro-elastic coat and a double row of flattened columnar epithelium. Between the tubules there is connective tissue with many leucocytes in it. Between the basement membrane and the epithelial cells are some cells arranged in groups, spoken of as the crescents of Gianuzzi. They correspond in position to the parietal cells in the glands of the stomach. They do not contain mucin, are different in appearance from the other cells which do contain mucin and are clear and swollen. (b) There is on the other hand the serous salivary gland, represented by the parotid, which is also a compound tubular gland corresponding in structure to that already described, only that the epithelial cells are granular in appearance and there are no crescents of Gianuzzi. (c) We have again the third variety which is a mixed salivary gland, represented by the sub-maxillary gland. It consists of basement membrane, epithelium and a duct with muscle fibres arranged longitudinally upon it. In appearance it resembles both glands above described being a mixture.

These glands are well supplied with blood, the vessels forming networks around the tubules. Small spaces between the tubules represent the lymphatic system. Nerves of both varieties are present.

The Pharynx. — The wall of the pharynx is formed in three different layers, (a) a mucous coat, which above the level of the soft palate is lined with ciliated epithelium of the stratified type, below that by a scaly epithelium also stratified. It contains also many mucous glands and papillae. There is also a considerable quantity of adenoid tissue, particularly in the respiratory portion where it forms on the posterior wall the third or pharyngeal tonsil. (b) Beneath the mucous coat lies a muscular, which consists of striated muscular fibres and are the constrictor muscles of the part. External to this there is (c) a fibrous coat which consists of dense fibrous and elastic tissue — fibro-elastic. The blood vessels, lymphatics and nerves are distributed in the same way as in the mucous membrane of the tongue.

The Oesophagus. — The oesophagus is constructed from tissues arranged in layers in such a way that we can distinguish (a) a mucous layer, which consists of stratified epithelium and underneath the epithelium a tunica propria or corum covered with small papillae extending into the epithelium. Beneath this there is the longitudinal muscular fiber of the involuntary type spoken of as the muscularis mucosa. Just external to this we have (b) the sub-mucous coat, consisting of loose connective tissue, with small mucous glands in the upper portion of it. Still external

to this we have (c) the muscular coat arranged in layers so as to form an inner circular and an outer longitudinal layer. In the upper portion of the tube the muscle fibre belongs to the voluntary type, the lower portion to the involuntary. (d) The outer coat which consists of connective tissue and elastic fibres. The blood-vessels, lymphatics and nerves are distributed as in the pharynx, with this additional, that the nerves terminate in plexuses with ganglionic cells between the muscular layer as in the stomach and intestine.

THE STOMACH.

The stomach is a hollow organ situated anatomically in the left hypochondrium, epigastrium, and partly in the right hypochondrium. It is continuous with the oesophagus and the intestine being simply a dilated and differentiated portion of the gastro-intestinal tract. It has two orifices — the cardiac and pyloric — and two curvatures, a lesser and a greater. It is composed of four layers or coats, the first are serous being a reflection of the peritoneum which covers the organ except at the lines of the greater and lesser curvatures. It consists of connective tissue and elastic fibres and is covered with a single layer of endothelial cells. The second coat consists of muscular fibres of the non-striated variety which may be divided into three distinct layers, (a) longitudinal layer which is external and better developed at the curvatures, (b) a circular layer which completely invests it; it is specially developed at the pyloric end and forms with the fold of the mucous coat the pyloric valve, the muscular band being called the pyloric sphincter, (c) the oblique set of fibres not completely investing the organ. The third or submucous coat consists of loose connective tissue with some elastic fibres. In this material lie the blood vessels, lymphatics and nerves. Between this and the next or mucous coat is interposed the muscularis mucosa, which is made up of plain muscular fibres divided into external longitudinal and internal fibres. The fourth coat is most important; it is thicker and more vascular than any other part of the alimentary canal. When the stomach is empty the mucous membrane is thrown into rugæ or folds along the lower curvature, but these are not permanent. The mucous membrane is covered with a single layer of columnar epithelium and on examination shows pits or depressions scattered over its surface. These are the enlarged mouths of the tubular glands and are most distinctly seen towards the pyloric orifice, where around this margin are little fringe-like processes which are rudimentary villi. Opening into these alveoli are the ducts of mucous tubular glands. These gastric glands are of two varieties, (1) the cardiac, or as some

call them, the peptic, and (2) the pyloric, so called because of the greater number of the particular type at the particular orifice of the stomach — both varieties being limited to the mucosa. The cardiac glands have a lining of columnar or pyramidal epithelium which is spherical or cuboidal at the neck — they are known as the central or chief cells; they secrete the pepsin of the gastric juice and have been spoken of as "peptic cells." In addition to these central or chief cells there are "superadded" or parietal cells, each of which communicates with the lumen by a fine canal passing between the central cells; they are more numerous towards the neck of the gland and are triangular or spheroidal in shape. They lie between the basement membrane and the central cells. The pyloric glands have long, wide ducts into which the glands open. The tubules are tortuous and often have expanded extremities. They are lined with columnar or cubical epithelium cells which in the fresh condition are granular in appearance. They have only one variety of epithelium cells and that corresponds to the central cells of the cardiac glands. These glands are not absolutely located at the cardiac and pyloric ends as the terms would seem to indicate, but are simply more numerous in the respective portions. A peculiarity in the glands takes place at the pylorus; they become more elongated and are continued into the submucosa and are evidently transitional to the glands of Brunner to be referred to later, the mucularis mucosa is absent at this place. In addition to this, at the pyloric orifice around the gastric glands, adenoid tissue is found and this is spoken of as the lenticular gland.

The blood vessels are abundant, they pass along the curvature where the serous coat is absent. They divide in the submucosa and form networks around the base of the lymphatics. Near the mouths of the glands a venous network encircles them and from these networks veins pass along with the accompanying arteries. The lymphatics accompany the blood vessels, forming a plexus in the submucosa, a fine network is found in the mucosa, these end beneath the epithelium between the glands in dilated, blind extremities. In addition to this set of lymphatics in the mucosa and the submucosa, the muscular fibres have their own lymphatics, these lie between the two principal layers of muscle. The nerves enter the serous coat and form a plexus with ganglia between the longitudinal and circular muscular fibres — plexus of Auerbach; these supply the serous, longitudinal and outer part of the circular muscular coats. A continuation of these fibres inward forms another ganglionic plexus in the submucosa — plexus of Meissner. From these latter plexuses fibres pass and are distributed beneath the epithelium of the glands.

The Small Intestine. — The small intestine is a tube about 20 feet in length and is divided into three parts, (1) the duodenum, about 10 or 12 inches long, with the peculiarity that it has no mesentery. The remainder of the intestine is coiled up in all directions and is attached to the posterior abdominal wall by the mesentery or peritoneum. This mesentery consists of a double layer of peritoneum with the blood vessels, lymphatics, some adipose tissue, and nerves between. The two remaining parts being (2) the jejunum and (3) ileum, although there is no distinct division between them. The walls of the small intestine are comparatively similar to those of the stomach. There are only two layers of muscle — the oblique layer being absent — and there is the modification and specialization of the mucous membrane; the surface of which is covered with numerous threadlike, filiform processes — the villi. In addition to these elevations or villi, folds running transversely in the direction of the lumen are seen particularly at the upper part; these folds are called valvulae coniventes. Within the mucous membrane are many tubular glands or crypts of Lieberkuhn, which are lined with columnar or spherical epithelium, some of which undergo mucoid distention and are converted into the goblet cell. These glands open at the base of the villi. At the duodenum these glands are well marked. In addition to the glands of Lieberkuhn, however, there are in the duodenum the compound tubular or racemose glands of Brunner. These duodenal glands, as they are sometimes called, lie in the submucosa and open by a long duct between the villi. While speaking of glands there are two other varieties: (1) the solitary glands, which are found scattered throughout all the length of the small intestine (also found in the stomach and large intestine) but most extensively in the ileum. They consist of lymphoid cells, some connective tissue, and are within a capsule. (2) The agminated glands or Peyer's patches; these are mostly in the lower portion of the ileum and consist of a number of lymph follicles and adenoid tissue. The patches vary in size, from one-half to two inches in length, about half an inch in breadth and run in the long axis of the intestine and generally from 20 to 30 patches are present; they are better developed in the young than in the aged.

The villi consist of the tissues of the mucosa, some fibres from the muscularis mucosa, in the center a lacteal, surrounded by a capillary network which connects the afferent artery and the efferent vein, and some connective tissue which binds the different parts together. They are covered with a layer of epithelium which sometimes shows striation; goblet cells are also seen.

The Large Intestine. — It is about five feet long and divided into the following parts: (1) caecum with vermiform appendix; (2) ascending; (3) transverse; (4) descending colon; (5) sigmoid flexure; and (6) rectum. The structure is comparatively similar to that already given with these modifications; at the lower part the serous coat is absent, the longitudinal muscular fibres are developed in three bands and not uniformly around the tube, they are sometimes shorter than the tube and hence the characteristic sacculation and the circular fibres are little developed between them. The mucosa is smooth, has no villi but contains simple tubular glands — the glands of Lieberkuhn — which are covered with columnar cells. The goblet cells are in greater abundance than in the small intestine. The rectum is somewhat different, it has no sacculations, the longitudinal fibres being developed around the whole tube; the circular fibres are extra well developed especially low down where they form the sphincter, the mucosa is thicker and more vascular and it has no serous covering, there are also some compound racemose, glands, (anal glands,) at the lower end.

The blood vessels are much like those in the stomach, they pass through the serous and muscular coats giving off branches to them, into the mucosa and there form a fine network. Branches pass to the mucosa and form fine capillary networks around the glands and the mouths of the follicles. Veins pass from this superficial network and join the deep veins. Where villi exist additional arteries pass to the base where they form a network, around the lacteal ending in veins which pass to the deeper veins. The glands of Brunner, the solitary and agminated follicles get their supply from the submucosa. The lymphatics are abundant. They originate as a blind canal and lie in the mucosa between the tubular follicles. Every villus has a central vessel, a lacteal or chyle-vessel. These all join a plexus in the mucosa, but in the submucosa another plexus is situated, there being a frequent anastomoses between them. All unite and pass between the layers of the mesentery joining the main lymphatic system.

The nerves are arranged just as in the stomach. The plexus of Meissner give off fine fibrillae to the villi. Also to the glands where they form a fine plexus.

THE LIVER.

The liver is a gland of the compound tubular variety. This tubular character is not well shown in the human structure, but in some of the lower forms of the vertebrates this condition is very well marked, as in the pig. On making an examination of the minute structure of this organ, we find that it is divided into areas which are polygonal in shape. These

areas are what are termed the lobules. This division into lobules is not at all complete in man, where we find the outlines very poorly defined, but when we come to the hog we find that this separation is complete and we have a well marked differentiation of the liver structure into these areas or lobules. These lobules are somewhat prismatic in form, having an apex which is more or less rounded in appearance and a base which is blunt. The arrangement of these lobules varies, on the outer surface of the organ we find them arranged at right angles to the surface, with their apices directed towards the periphery, while in the center of the organ they are arranged more or less irregularly. Between these lobules and binding them together, there is a layer of connective tissue. This connective tissue is derived from, or rather is a continuation of, that which covers the surface of the organ. It enters the liver at the transverse fissure along with the blood vessels and the hepatic duct; and passes into the substance of the liver supporting these vessels, the only function it seems to have being to support and bind together these structures in their ramification through the liver tissue. This is what is known as the capsule of Glisson, and it is owing to the fact that this so-called capsule does not completely surround the lobule, that we have difficulty in distinctly limiting the margin of the lobule in the human liver.

Each of these lobules consists of irregular shaped, nucleated and granular cells, (the true hepatic cells,) arranged in radiating rows from the center towards the margin; blood capillaries, and the so-called bile capillaries. The blood capillaries extending from the inter-lobular (portal) vein to the intra-lobular or central vein. These true hepatic cells are variable in size, sometimes multi-nucleated, containing granules of pigment and sometimes globules of fat, they have no cell-wall. These cells are united forming cords, the so-called cords of cells, lying among the blood vessels. Between these rows of cells lie the bile capillaries, which are formed simply by the close approximation of one row of cells to its neighboring row of cells, in other words, we have a hollow groove on each cell, which on being approximated to another cell with a similar hollow groove forms the channel for the bile to flow, in fact is the lumen of a simple tubular gland. This explains the reason why the different experimenters have never been able to find an epithelial lining to these bile capillaries, because they are not true bile capillaries, but the lumina of many simple tubular glands. The blood capillaries are the branches from the inter-lobular vein, they are very small in size, though somewhat variable. They communicate freely with one another during their course through the lobule,

converge and open into the central or intra-lobular vein. These central veins converge and form the sub-lobular vein. We have thus a very close connection between the blood vessels, the secreting cells and the bile capillaries or channels through which the secretion passes.

We have in the liver two systems of blood-vessels, that which is represented by the portal vein, which really performs the function of an artery, carrying the blood from the general circulation to the liver tissue, in order that it may be acted upon by the hepatic cells, and the hepatic artery which carries the blood to the liver for the nutrition simply of the tissue. The blood in both cases passing through the intra-lobular capillaries into the intra-lobular veins, afterwards through the normal venous channels. The portal vein, the hepatic artery and the bile duct or hepatic duct, are situated as has been already indicated, between the lobules, and bound together by the connective tissue.

The bile duct is formed by the union of the bile capillaries. The walls of the bile duct being formed by a strong membrane of connective and elastic tissue, muscular tissue being present in the walls of the larger ducts, the inner surface being covered by a layer of columnar epithelium. These smaller bile ducts unite with one another, until we have ultimately formed the cystic duct, or the ductus cholevochus, which passes out at the transverse fissure and opens into the duodenum, in common with the duct of the pancreas.

The gall bladder is simply a dilated bile duct, the walls being similar to the larger ducts, the muscular tissue being better developed; sometimes with an outer fibrous coat in addition and the mucous surface thrown into rugae or folds.

The liver as a whole is made up of masses of these lobules arranged together in such a way that it can be sub-divided into several parts or lobes. Each of these lobes is made up of lobules, each lobule having the structure already indicated. It is common to speak of the liver as consisting of five of these lobes, the right, which is the largest; the left; the lobe of Spigelius; the caudate and quadrate lobes, the terms used signifying the position of the first two in regard to the body, the next, the name of the person first calling attention to its presence, and the latter two on account of their shape. It is the largest gland in the body, has several surfaces and several fissures. The upper surface is convex and in contact with the diaphragm, the under surface is uneven and comes in contact with the other organs in the abdominal cavity which lie in that region, the posterior surface, which lies in contact with the posterior wall, slopes off gradually

so as to meet the under surface. There are three principal fissures, the transverse fissure, within which lie the vessels, the longitudinal fissure and the fissure of the vena cava.

The liver, like all the other abdominal organs, has a covering of peritoneum, which entirely surrounds it, except at the transverse fissure. In addition to this peritoneal covering, there is a fibrous structure which surrounds the liver, the union of these two, that is the true peritoneum and the fibrous, forming the capsule of the liver. This capsule, that is the fibrous portion of it, consists simply of fibrous tissue and some elastic fibres. It is well developed at the transverse fissure, and its continuation inward into the substance of the liver which has been already referred to, is the capsule of Glisson. The peritoneal portion is external and has the same structure as the peritoneal structure already referred to.

There are two distinct sets of lymphatics in the liver, a superficial set associated with the capsule, and a deeper set which accompanies the portal vein, passes along with the intra-lobular capillaries to the central vein, afterwards along with the central vessels. The superficial set and the deep communicate with one another. Some writers claim that there is another set passing along with the bile capillaries, but this has not been sufficiently established to be accepted as an independent set.

The nerve supply of the liver consists principally of non-medullated fibres, but we also have some of the medullated variety present and intermingled among the other variety. They enter the liver structure with the hepatic artery, and accompany its ramifications in the interior of the organ; the character of the nerve terminations in this gland has not, up to the present time, been fully understood. Ganglion-cells are distributed along the course of the fibres.

THE PANCREAS.

The pancreas is a compound gland of the tubulo-racemose type resembling somewhat the serous salivary glands, but differing from them in the arrangement of the alveoli. The alveoli of the pancreas being more elongated and approaching more the tubular condition and hence the term applied to the gland as a whole. It is sometimes spoken of as the "abdominal salivary gland." It is a narrow elongated body and lies immediately behind the stomach.

On making a section of the gland it is seen to consist of a great number of portions of gland substance, the acini, which can be grouped into somewhat irregular areas or lobules, these again being grouped, although

somewhat irregularly, into the so-called lobes. The lobes are separated from one another by a loose connective tissue, which, passing between the gland substance in the form of fine septa, separates the tissue into the different parts already referred to. In the connective tissue lie peculiar groups of epithelial cells richly supplied with blood. The function of these cells is very obscure but their presence is always indicative of the pancreatic tissue. The remainder of the tissue of the gland consists of the cells which line the acini and the basement membrane upon which they rest. These cells are columnar or polyhedral in shape, are large enough to fill nearly the whole of the lumen of the acinus, are granular towards the center and quite clear at the margin, the granular area being more marked after periods of rest and vice versa. The cells are distinctly nucleated. The small ducts of the acini open into larger ducts and this converging of these ducts results ultimately in the formation of the main duct. This duct is formed by a single layer of flattened epithelium lying upon the strong coat of fibrous tissue which is external. This duct unites with the common bile duct and opens directly into the duodenum.

The blood is conveyed by the arteries which run in the connective tissue between the lobules, ultimately forming networks in the acini under the basement membrane, then forming the veins which pass along with the arteries in the connective tissue. The lymphatics pass also along with the arteries, their ramifications being somewhat uncertain, but some claim that the clefts between the lobules are lymph channels. The nerve fibres are in direct contact with the basement membrane but have not, as yet, been traced further.

THE LYMPHATIC SYSTEM.

The lymphatic system consists of several parts which we require to consider separately. It is very intimately associated with the digestive process and for that reason may be taken up in this particular connection.

(1) The Vessels. — These are the channels through which the lymph flows. They are variable in size, are composed of definite coats, the smaller — the lymph capillaries — forming irregular networks and are sacculated, that is to say are of unequal size. The smaller vessels have only one coat, which corresponds to the intima, or inner coat of the others. It consists of endothelial cells and a delicate network of elastic fibres. The larger ones, in addition to this inner coat, have a central, which consists of involuntary muscle fibres running in a circular direction, with a few elastic fibres; and an outer coat of firm connective tissue. In regard

to the distribution of these vessels they are found throughout the whole of the tissues of the body. It is claimed by some that they form an entirely closed system, that is, that their finest distribution is limited by walls, on the other hand many hold that their peripheral terminations open into the spaces in the cellular tissues. If the former view is correct then the fluid enters by endosmosis, if the latter, through the open ends of these vessels.

(2) THE GLANDS. — These are irregular in size and shape, and are distributed along the course of the vessels. They have a distinct capsule of fibrous tissue and involuntary muscle, which, in addition to forming the capsule, sends septa into the substance of the gland, which form the framework or the trabeculae of the gland within which lie the gland substance proper. The gland tissue consists of retiform connective tissue, the spaces filled with lymph-cells. It is arranged so that it forms spherical masses which lie at the periphery and elongated cords lying at the center, giving rise to the terms peripheral in the one case and medullary in the other. The medullary portion comes to the surface at the hilum, where the efferent vessel or vessels pass out. Between these peripheral masses and medullary cords, on the one hand and the trabeculae on the other, are spaces lined by flat cells, these are the lymph-spaces or lymph-sinuses. The lymph after passing into the gland through the capsule in the afferent vessels, passes through these sinuses, gathering up lymph-cells as it passes and then leaves the gland through the efferent vessels as described above.

The blood supply to the gland enters at the hilum, the gland structure receiving the greater part through the well developed capillaries, being returned by the veins which run alongside of the arteries. A few small vessels enter the capsule and are distributed in the capsule and the trabeculae. The nerves are of both varieties, few in number and irregularly distributed.

(3) LYMPH FOLLICLES. — In the different parts of the body there are more or less diffused or concentrated masses of adenoid tissue, which really belong to the lymphatic system, seeing that from them we have lymph cells passing. We have already spoken of the solitary glands and the Peyer's patches in the walls of the intestine, they are simply masses of gland tissue lying underneath the epithelium. Similar masses are also found in the tongue and at the back of the mouth where they form the tonsils.

The tonsils are two masses of adenoid tissue placed on each side of the fauces. The gland tissue is covered with stratified epithelium which

dips down into the tissue and forms the crypts or pits which are so characteristic of the tonsil. Along the walls of these crypts are aggregations of small lymph follicles, this appearance being due to a closer arrangement of the lymph-cells and explains the reason for the term compound lymphatic gland sometimes applied to the tonsil.

They are well supplied with blood, capillary networks both of blood and lymphatic vessels encircling the tonsil. Nerves are distributed to the tonsil also.

(4) Lymph. — As we have already indicated, we now look upon lymph as a tissue, because it consists of cells and intercellular matter. It is a fluid tissue, the liquid part or plasma resembling the fluid part of the blood not only in appearance but also in its composition. The cells or lymph-corpuscles are small and variable in quantity, being more numerous after passing through the lymphatic glands and similar in appearance to the white cells of the blood. Lymph is white in color when collected from the intestine, this color being due to the fine guanules of fat which it contains. The term chyle is applied to this fluid from the intestinal tract and the vessels through which it flows are called lacteals, but chyle is simply lymph from a particular place and the lacteals lymph vessels through which this milky fluid flows.

The Thymus Gland. — This gland consists of lymphoid tissue with septa of connective tissue so distributed as to give the gland a lobulated appearance. It is normally present in the embryonic and early period of infant life, rarely in later stages of life. Each of these lobules is divided into a central or medullary portion and a cortical or peripheral portion. This appearance is due to the passing of the strands of connective tissue from the septa already referred to, into the substance of the lobule for a greater or less distance and also the arrangement of the cells so that they are either loosely or else closely packed together. The structure of the gland is very similar to the tonsil or the ordinary lymphatic gland, if any distinction is appreciable, it is that the cells are more flattened, sometimes existing in groups. The gland is well supplied with blood vessels and several lymphatic vessels pass out from the gland.

The Spleen. — This is one of the so-called blood glands and may be considered a compound lymphatic gland, it is also spoken of as a ductless gland. It consists of a capsule and gland tissue proper, or as it is often called the spleen pulp. The capsule consists of fibrous tissue, elastic fibres and in some cases although very rarely in man, involuntary muscle fibres, but in addition to this, there is the reflection of peritoneum which, in this

like all the other abdominal organs, forms the serous coat or covering. This serous coat is of the same structure as other serous coverings and entirely surrounds the organ except where it is in contact with the stomach, diaphragm and at the hilum. The capsule — that is the capsule proper — sends off prolongations which enter the gland and extending between the walls, formed on either side by the capsule, form the trabeculae or framework of the gland, within which framework lies the lymphoid tissue. This lymphoid tissue consists of loose adenoid and vascular tissue within which there are dense adenoid tissue masses of variable size, usually small, constituting the Malpighian cells or corpuscles. The loose lymphoid tissue or spleen pulp, consists of connective tissue cells with many branches which unite with one another in the form of a network in the meshes of which lie large amoeboid cells with pigment granules — the splenic cells — multi-nucleated cells, lymph cells — leucocytes — and red blood cells. The walls of this network are lined with endothelium and in this way we have the spleen just like a sponge entirely hollowed out by these cavities within its substance. The Malpighian cells are formed by the peculiar development of adenoid tissue in the outer coats of the small branches of the splenic artery which has left the trabeculae and entered the surrounding tissue. They correspond in structure to the sub-divisions of a lymphatic gland.

The supply of blood is considerable and its distribution important. The splenic artery enters at the hilum, gives off branches to the trabeculae, some of which continue in the trabeculae throughout their entire course, others pass out into the lymphoid tissue and ramify through it. So soon as these branches get into the spleen pulp, adenoid tissue becomes developed in their outer walls and this adenoid tissue at certain points increases so that we have the Malpighian cells produced. Both of these sets of blood vessels, that is those within the trabeculae and those passing into the spleen pulp, open in their ultimate ramifications into the spaces between the branched connective tissue cells. Veins begin at these spaces and unite forming larger veins which run along with the arteries leaving the spleen at the hilum. The manner of communication between these arteries and veins is not clearly understood. It is generally agreed that the arteries terminate in capillaries and that the veins begin in capillaries, but it is still a question of doubt whether there be a direct communication between these two sets of capillaries. Some writers claim that there is an absolute communication, others that the arteries terminate and the veins begin as open vessels. If the former view is correct, we have a point in

the vascular system where the blood passes without being absolutely limited, in other words we have an open circulation at this point. If the latter view be correct we have a circulation similar to the circulation in general, but we have left unexplained the function of these intermediate spaces in the tissue of the spleen.

The lymphatics can be distinguished into a superficial set distributed partly in the trabeculae, partly in the capsule — this set in the human spleen is somewhat scanty — and a deeper set in the substance of the spleen communicating with the gland substance. The nerves are of both varieties, mostly medullated. They run along with the blood vessels and some of them have ganglia developed upon them. Plexuses are formed also in the spleen pulp.

THE HEART AND THE BLOOD VESSELS.

The heart is a hollow muscular organ situated in the thoracic cavity, consisting of muscular fibre, an external membrane (the pericardium) and an internal membrane (the endocardium).

The muscle fibre of which the bulk of the heart consists has already been described in connection with muscular tissue. The arrangement of the fibres in the walls of the heart is somewhat complex, there being a complete separation of the muscular tissue in each of the chambers, that is to say, the fibres in the walls of the auricles have no communication with the fibres in the walls of the ventricles. There is a firm tendinous membrane separating the auricles and ventricles from each other, spoken of as the annuli fibrosi, which is of considerable importance in the formation of the valves. Between the muscle fibres there is a quantity of connective tissue in which the vessels ramify.

The pericardium is a connective tissue structure with a covering of endothelium on its free surface. It is so arranged that it forms a sac forming a covering to the external surface of the heart and reflected backwards in such a way that a space is formed between the two surfaces, this space is spoken of as the pericardial sac. Underneath the pericardium there is a layer of tissue, the sub-pericardial tissue, which consists of areolar connective tissue with many fat cells in the spaces.

The endocardium forms the inner covering of the heart and is also a connective tissue membrane, resembling the pericardium, having elastic fibres in the tissue and the free surface covered with endothelial cells. It is continuous with, in fact might be looked upon as a prolongation of the inner coat of the blood-vessels. The valves of the heart are formed by a

double layer of this endocardium, with the fibro-elastic connective tissue referred to as the annuli fibrosi between. If muscle fibre is present it is only at the base of the valve where it can be found.

The blood supply for the nutrition of the heart is derived from the two coronary arteries, the muscle fibres being well supplied with blood from an extensive capillary system. The lymphatics are very numerous, extensively distributed in the muscular tissue and form in the endocardium and pericardium networks which are widely distributed.

THE BLOOD VESSELS.

THE ARTERIES. — The walls of the arteries can be divided into three different coats, which are somewhat modified according to the size of the artery. In the small arteries, the inner coat or intima consists of a layer of endothelial cells and a very fine membrane consisting of a fine network of elastic fibres known as the internal elastic membrane. The middle coat, or media, consists of a single layer of involuntary muscle fibre arranged in a circular direction. The external or adventitia consists of connective tissue and elastic fibres. The medium sized arteries have in the inner coat the same endothelium, a well developed elastic membrane and between these two some fibrous connective tissue, flattened cells and elastic fibres. The middle coat consists of several circular layers of involuntary muscular fibres and many elastic fibres. The external coat has increased considerably in thickness, the elastic fibres forming an external elastic membrane and frequently there are involuntary muscle fibres running in a longitudinal direction. In the larger arteries, such as the aorta and pulmonary artery, the intima is thickened on account of the extra development of the sub-endothelial tissue which becomes quite fibrous, and the elastic layer which forms the fenestrated membrane. The media has the elastic tissue increased, in some cases forming layers which alternate with the muscle fibres. The adventitia differs slightly from the medium sized vessels and that difference consists chiefly in this that there is no external elastic membrane.

THE VEINS. — It is common to refer to the three coats in veins just as we do in the arteries, but seeing that the media is very slightly developed some histologists speak as if there were only two coats. The inner or intima consists of endothelial cells, an internal elastic layer of fibres and more or less of a sub-endothelial layer; these two latter layers being somewhat irregularly developed, depending to some extent on the vessel referred to.

The media is variable but consists of circular involuntary muscle fibres, elastic fibres and connective tissue in greater or less degree of development.

The adventitia consists of longitudinal muscle fibres, connective tissue and some elastic fibres. This coat being quite as well developed as the same coat in the arteries.

The valves of the veins are simply folds of the intima with some fibrous tissue developed to aid in carrying on their function.

The Capillaries. — These are the vessels which establish a communication between the arteries and the veins. The walls of the capillaries proper consist of one single coat, being the continuation of the internal coat of the arteries and the veins. The wall consists of a simple layer of endothelial cells kept together by a very little cement substance, the representative of the internal elastic layer of the other vessels. At one time it was said that arteries had three coats, veins had two and capillaries had only one, which we now know to be incorrect, but we can easily see how the idea originated.

The medium and large sized vessels have a blood supply of their own, the vessels running chiefly in the outer coat. Nerves are distributed to all the vessels even in the capillaries, and the lymphatic vessels are closely associated with the walls of the different vessels.

RESPIRATORY TRACT.

The different parts associated with the respiratory process are the nasal passages, the larynx, the trachea and the lungs.

The Nasal Passages are covered with mucous membrane which is somewhat variable in structure depending on the function of the particular part on which it is distributed. We find that the mucous membrane covering the external portion of the passage, that is the first portion of the respiratory tract, is simply a modified integument consisting of an external layer of stratified squamous epithelium lying upon a basement or tunica propria, within which are the sebaceous glands and the hair follicles. There is, however, what is spoken of as the respiratory portion of the nasal passages and that includes all the nasal passages and accessory spaces except the upper portion of the superior turbinate bone and the upper part of the septum. This respiratory portion is lined with stratified ciliated epithelium, with some goblet cells in it and resting upon a tunica propria of considerable thickness consisting of fibrous connective tissue and leucocytes, with small tubular glands, both mucous and serous, in the

fibrous tissue. The portion of the nasal passage not included in the respiratory region is what is known as the olfactory region where there is a specialized epithelium lying on the tunica propria. The olfactory epithelium consists of two different varieties of cells, the one being slender, elongated and nucleated, with two extremities or poles the one pole reaching to the free surface, the other extending towards the deeper structures and forming the axis-cylinder of the nerve fibre, being what we referred to previously as the special ending of a nerve fibre; the other variety of cells are simply supporting and consist of a broad columnar end towards the free margin and a fine or tapering end towards the deeper structures. The free surface of the membrane is covered by a very fine membrane — the membrana limitans olfactoria — through which the olfactory cells throw their ciliated extremities. The tunica propria upon which this epithelium rests, consists of loose connective tissue fibres with some fine elastic fibres distributed amongst them and the so-called olfactory glands embedded in the substance of the tissue. These glands are mucous in function and may be either simple, or branched tubular in type. They were always considered serous until recently and are sometimes spoken of as Bowman's glands.

The blood vessels form a very rich capillary network in the tunica propria just underneath the epithelium. The veins also form a dense network at the lower end of the inferior turbinate bone giving to it the peculiar cavernous character which it possesses. The lymphatics lie in the deep part of the tunica propria, those in the olfactory mucosa communicating through the cribriform plate of the ethmoid bone with the spaces within the cranial cavity.

The terminal branches of the tri-facial nerve are distributed in the tunica propria not merely of the respiratory but also of the olfactory mucosa and probably also send twigs to the epithelium seeing that small fibres are found there also.

The Larynx is covered with epithelium which for the most part is of the stratified ciliated columnar type. On the true vocal cords, the epiglottis and a portion of the arytenoid cartilages, the epithelium belongs to the stratified scaly variety. The epithelium lies upon a basement or tunica propria, which is made up of elastic fibres, white fibrous tissue, some white cells or leucocytes and in the deeper parts some tubular mucous glands.

The cartilages are mainly hyaline, those belonging to this type being the thyroid, the cricoid, and part of the arytenoid, the remainder being of the yellow elastic variety. The vocal cords are composed of elastic fibre.

There is a rich supply of blood distributed by means of the networks of vessels in the tissue. There are two sets of lymphatics, one superficial beneath the epithelium and the other deeper, but both communicating freely with each other. The nerves are distributed throughout the tissue, some of them terminate in end bulbs and some as taste-buds.

The TRACHEA or wind pipe consists of fibrous and muscular tissue with cartilaginous rings or parts of rings in the anterior wall giving support and keeping the surfaces apart. The inner surface is covered with ciliated epithelium similar to that in the larynx. This epithelium rests upon a basement membrane which is comparatively thick, the elastic fibres forming a distinct network, underneath which lies some areolar connective tissue with some small mucous glands and blood vessels in its substance. External to this we have the cartilaginous bands which are of the hyaline variety and encircle the anterior portion only; the posterior, that is the part between the ends of the partial rings, being composed of muscle fibre of the involuntary type extending in a longitudinal direction. In the posterior wall still external to the muscle-fibre layer there are frequently small glands distributed sometimes opening into the trachea through all these other structures.

The blood vessels, lymphatics and nerves are distributed in a similar manner to that already described in connection with the larynx.

The BRONCHI are formed by the bi-furcation of the trachea and in structure are similar to the trachea. These bronchi divide in a di-chotomous fashion and as the result of this continuous division the smaller or terminal bronchi are formed, the structure of which is simply modified. The mucous membrane is thrown into longitudinal folds and the epithelium gradually becomes reduced to a single layer of cells resting upon the basement membrane. The muscle fibre forms a distinct circular layer and extends as far as the finest bronchus. The cartilage is irregularly distributed and does not form definite plates or rings as in the trachea. There are tubular glands along the course of the bronchus as far as the cartilage extends, and these lie outside the muscular coat. The smaller bronchus terminates as a dilatation or infunbulum, the walls of which are thin and somewhat sacculated, each saccule being an alveolus.

The LUNG is formed simply by the aggregation of these alveoli and bronchi with a small quantity of connective tissue between, so that a description of the bronchus and the alveoli will include all that requires to be said in regard to the lung. The alveolus consists of an inner lining of epithelium of a columnar or cuboidal type and this practically includes all

that is different in the alveolus and the bronchus except that the wall is fibrous and elastic without any cartilaginous tissue and perhaps thinner.

The outer surface of the lung is covered by a membrane, known as the pleura, which consists of connective tissue with some elastic fibres and covering its free surface a layer of endothelial cells. It is so arranged in regard to the lung as to form a visceral layer and is reflected along the inner wall of the thoracic cavity forming a parietal layer, with the space between spoken of as the pleural cavity. It is a serous membrane like the pericardium.

The blood is carried to the lung tissue by the pulmonary artery which breaks up and follows the different bronchi, to the alveoli, where they form the capillary network just underneath the epithelium, they then pass into the vein at the base of the alveolus and pass out along with the arteries. This refers to the circulation of the blood for purposes of aeration and not for the nutrition of the lung tissue. The lung is nourished by blood carried to it by the bronchial arteries and distributed by the sub-division of these vessels.

The lymphatics are distributed in two different groups, one immediately underneath the pleura and another in the connective tissue which is scattered in the substance of the lung.

The nerves to the lung are derived from the sympathetic system and also from the cerebro-spinal, so that the fibres are both medullated and non-medullated.

THE SKIN.

The external surface of the body is covered by a complex structure which we speak of as the skin. The function of the skin is physiological and beyond the scope of our present investigation but it is worthy of note that in cases where the function was interfered with by covering the surface with some material, preventing the passing out of the perspiration, that death soon followed, this was illustrated in the case of the "gilded angel," so much referred to a few years ago.

It is common to distinguish between the outer, or horny, and the inner or true skin. The outer portion corresponds to the scarf skin, or the epidermis of the different writers, is of different degrees of thickness, and consists of different layers of squamous epithelium. When a section is made through a portion of this scarf skin, say from the palm of the hand, it is found to consist of the following different layers, beginning at the surface and passing inward, a layer of horny cells, which are quite dry and cornified, beneath this a layer still of horny cells, but not so dry, in

fact they are somewhat swollen and differ only in that respect from the cells above them. At the lower margin of these horny cells, a row of similar cells, with slight modifications, is found, the modification consisting in the development of certain granules in their substance and called granules of eleidin, the row of cells being referred to as the stratum granulosum, the granules sometimes dissolve and form a clear zone above this zone of a granular nature, the clear one being spoken of as stratum lucidum, because it is clear. Immediately beneath, we come to a mass of irregular shaped cells, the so-called prickle cells, which are formed simply by the passing of protoplasmic strands or bridges across from the one cell to the one beside it, in this way giving rise to the appearance described by the term prickle-cell. These cells rest upon a layer of cells which are columnar in shape and placed close to one another, between which the lymphatics and nerves ramify. The last two rows of cells are referred to collectively as the Malpighian layer or the rete mucosum.

When dealing with thinner skin, say on the face or parts of the body, the epidermis is less extensively developed, the granular layer being very thin and the clear zone — the stratum lucidum — wanting altogether. The horny cells proper being quite thin and compressed.

The true skin, or the corium, is made up of connective tissue, some elastic fibres and sometimes muscle fibres, more or less interwoven with one another. The portion in contact with the epidermis is in the shape of papillae, and on account of the fact that the papillae are clearly seen, it is common to speak of the papillary layer of the corium. Underneath this we find a zone of tissue which gradually merges into this papillary layer above, and at the same time blends with the loose, fibrous tissue and fat cells beneath, which constitute the subcutaneous tissue. This subcutaneous tissue being in close relation to the sheaths of the muscle or the covering of the bone.

The color, in case of the dark-skinned races, is distributed in the deep layers of the epidermis. The theories of pigment formation have already been referred to, they are briefly these, that connective tissue cells already pigmented, wander from the true skin into the epidermis, or what is much more likely, that it originates directly from the epithelium.

The true skin is well supplied with blood through the capillary networks which are distributed in the papillae and which send branches to the various appendages of the skin. The epidermis has no direct blood supply, receiving its nutrition through the structures adjacent.

There are two different sets of lymphatics, one deep in the subcutaneous tissue, the other superficial and associated with the skin and the different glands.

The nerves of the skin are quite important but have already been referred to in connection with the special terminations of nerve fibres. They are also related to the appendages of the skin to a certain extent, that is, to the glands and hair.

THE APPENDAGES OF THE SKIN.

NAILS. — The different appendages of the skin are the nails, the hair and the glands. The nails are dense horny plates corresponding to the stratum lucidum of the epidermis, consist of cells with the remains of a nucleus and lie immediately upon the corium or true skin, but specially developed in this case and spoken of as the matrix. The corium is normally in the form of papillae next the surface, but it is in the form of longitudinal ridges in this instance. It is common to speak as if the growth of a nail was simply from the matrix or portion of the true skin upon which it lay; but we have to consider it as being formed also from the edges of the matrix or that portion which remains under cover of the skin, this is shown in cases where the nail is removed and the after growth which takes place.

HAIR. — The hair is divided into the shaft and the root, the shaft being that portion which is external to the surface of the body, the root that portion which remains embedded in the skin within the hair-follicle. The hair-follicle is a depression in the skin formed by the invagination of a portion of the skin. Into these follicles several glands open, these are the sebaceous glands associated with the hairs. Each hair has a small muscle which consists of voluntary muscle fibres passing from the surface of the corium to the fibrous sheath of the hair-follicle. These muscles are so placed that when they contract, the hair is drawn upward making the shaft assume an erect position. It is necessary to notice, that hairs are placed in such a position that they do not pass directly through the skin in a straight line, but they do in an oblique direction, and the muscle lies in such a way that the hair is pulled straight when the fibres contract.

A cross section of the shaft of the hair brings out the structure of the hair. It is seen to consist of an outer covering, the cuticle, which is made up of transparent epithelial cells overlapping one another; a fairly thick fibrous layer immediately underneath the cuticle which makes the bulk of the hair and can be separated chemically into cells which are more or less

pigmented; and a central portion or medulla composed of irregular shaped cells with spaces between filled with air, giving the peculiar black appearance that this portion of the hair shows on section. The root differs only from the shaft in having an increase in the fibrous portion which is the bulb or knob that we see at the end of a hair when it is drawn out of the follicle. The root of the hair has sheaths derived in part from the connective tissue part of the skin and in part from the epithelial portion of the epidermis.

Hairs grow from the small papillae at the bottom of the follicle by an increase of the soft cells which cover them, that is the papillae. So long as the papillae remain active new hairs will grow but when they undergo atrophic changes, no more developments of hair take place. The large thick hairs in the face of some animals, which are tactile in function, have at their base a dilated veinous system which can be filled with blood forming an erectile tissue, and in this way the sensation is greatly increased.

Glands. — The glands of the skin are of different varieties; two groups being recognized. The sebaceous gland is the one already referred to in connection with the hair follicle. They are saccular, with one or more acini communicating with the ducts which open directly into the hair follicle. The ducts are lined with stratified epithelial cells, which are continued into the cells of a glandular type which line the saccules. The secretion is of a fatty nature and passes constantly into the follicle.

The sweat glands, or as they are sometimes called coil glands, are distributed over the body and lie in the true skin. They are tubular glands, greatly convoluted, and open on the surface through a very tortuous duct. They are very abundantly developed in the palms of the hands and the soles of the feet. The gland consists of a basement membrane and well marked glandular cells, with, in some cases, muscle fibre between; the excretory portion, that is the duct, is made up of fibrous tissue, lined with epithelium in part, but partly consists of a channel between the cells of the skin without any direct lining. The secretion is of an oily consistency, but may, in particular instances of nerve impulses, be of a watery nature, which is spoken of as sweat.

The glands in the ear, which are ceruminiferous in their function, are simply modified sweat glands and require no further description.

The blood supply, the lymphatic and the nerve distribution have already been referred to in connection with the skin, and all that requires to be said further is, that all of the appendages are richly supplied with vessels and nerves.

THE KIDNEY.

The kidney is a highly developed compound tubular gland, the minute structure and histological characteristic of which is extremely simple, when this point is kept clearly in view. The appearance of a section of the kidney to the naked eye is characteristic. It consists of a cortical or marginal area and a central or medullary — both of these areas consist entirely of tubules, the uriniferous tubules, but as these are sometimes straight and at others convoluted the kidney has a peculiar appearance. In the medullary area they appear as pyramids — pyramids of Malpighi — while in the cortex there is a division into a narrow zone with straight tubules — the medullary ray — and another zone with convoluted tubules and corpuscles of Malpighi — the labyrinth. The principal duct of the gland is the ureter which passes out at the hilum and has a dilated portion at its upper extremity the so-called pelvis of the kidney. It is into the pelvis that the uriniferous tubules open, the apices of the pyramids being free in the space. There are from eight to eighteen of these pyramids in each kidney.

The uriniferous tubules begin in the cortex as dilatations with a tuft or mass of blood capillaries, very much convoluted, within the dilatation — these are the Malpighian bodies. Each " body " consists of two parts, (1) the expanded portion of the tubule which forms a capsule or surrounding membrane to the contents known as the capsule of Bowman, and (2) the mass of convoluted blood capillaries. An afferent artery enters the capsule and divides into branches and again subdivides forming the capillary masses which are connected by loose connective tissue, the blood passing out by an efferent vessel which lies side by side with the artery. The capsule is lined with flat epithelium which is reflected over the capillary tuft. The Malpighian body has the tubule proper leading off from it. It begins with a very narrow constricted portion — the neck — which is usually in a position directly opposite to the vascular channel. Beyond the neck, the tubule becomes dilated considerably, is markedly convoluted and forms the first convoluted portion. This portion is lined with cubical epithelium which is granular in appearance and nearly fills up the whole lumen of the tubule. The epithelium cells frequently interlock with one another. Succeeding this we have the descending portion of the loop of Henle. This is the narrowest part of the whole uriniferous tubule. It begins at the division line between the cortex and the medulla. This portion is lined with flat epithelium leaving a relatively large lumen. The descending portion is connected to the ascending by a relatively wide por-

tion but lined by the same variety of epithelium as the descending. The ascending portion is the other limb of the loop of Henle, it is still wider but has an epithelium of a more cubical type. The ascending portion is succeeded by the second convoluted portion situated in the cortex, and differs only from the first convoluted in that the epithelium is more elongated and the nuclei larger. The remaining portions of the tubule are a connecting tube with cubical and columnar epithelium, and the duct of Bellini which opens at the apex of the pyramid with columnar epithelium. The wall of the tubule throughout being the basement membrane. Between the tubules which are closely associated together is a very small amount of connective tissue, this represents the interlobular tissue of other organs.

The blood vessels are very numerous. The artery enters at the hilum, passes the submucous tissue of the wall of the pelvis and gives off branches for the nutrition of the parts around. Before passing into the glandular structure, the artery branches, these pass between the pyramids to the junction of the cortex and medulla where they give off two sets, (1) the interlobular cortical, and (2) the straight arteries of the medulla. The straight cortical, gives off branches towards the surface of the afferent vessels of the glomeruli. These form the Malpighian tuft ending with the efferent vessels which are smaller and carry off the still arterial blood. These form networks around the tubules in the cortex, are taken up by the interlobular veins accompanying the arteries and then go to the pelvis assisting in the formation of the large renal veins. The straight arteries of the medulla form networks in the interlobular tissue forming capillaries around the orifice of the ducts at the apices of the pyramids. The blood is taken up by the straight veins at the junction of the cortex and medulla, from there they pass obliquely through the medulla to the pelvis where they join the other from the renal vein.

The lymphatics constitute a superficial set within the deeper layer of the capsule and a deeper set which accompanies the blood vessels communicating with those in the connective tissue.

The nerves are distributed in the parenchyma along with the blood vessels. They form networks around the blood vessels. Small fibrillae are said to exist between the tubules forming plexuses outside the membrane proper.

THE CENTRAL NERVOUS SYSTEM.

The Brain. — It is common to speak of the central nervous system as consisting of two parts, the brain and the spinal cord, but that is a super-

ficial distinction, and exists only in the adult state; that is to say in early foetal life the whole system exists as one single cord. It is formed in the embryo from a groove which appears on the surface of the epiblast, the approximation and union of the edges forming a tube with a central space; the canal of the cord and the spaces in the brain. The walls of the tube forming the cord become equally thickened and remain straight, but the portion forming the brain becomes thickened irregularly and bends on itself, so that ultimately with the changes taking place in the tube, in addition to those mentioned, we have what is spoken of as the brain. The whole of the substance of the brain and the cord is composed of white and grey matter, as it is technically called. The white matter consists of medullated nerve fibres, without nerve cells and is somewhat less vascular than the grey. The grey matter consists of nerve cells and some nerve fibres which are supported by some neuroglia — a form of connective tissue already referred to. In the cord the white matter is superficial, but in the brain the grey matter is on the surface, in addition to certain other parts in the substance.

The term brain is applied to all of the mass of nervous structure which lies within the cranial cavity. It consists of several different parts which it will be necessary to refer to, even though it may not involve strictly a histological description to do so. The greater portion of the brain is made up of the cerebrum, that is the portion in front and above, speaking in relation to the position the brain occupies when the body is in the erect posture. The cerebrum consists of two lateral halves separated from each other by the longitudinal fissure and connected at the base of the fissure by the corpus callosum. They are arranged so that the outer surface is convex and corresponds to the concavity of the inner surface of the vault of the skull; the surfaces coming together at the longitudinal fissure being flat. The outer surface is convoluted, that is, the superficial grey matter is folded upon itself in such a way as to form a very much increased area of surface, in this way allowing a considerable surface in a limited space. The spaces between the convolutions are spoken of as sulci, and if they are better developed they are called fissures, so that the different areas of the brain surface can be spoken of and distinguished from one another by these sulci or fissures.

The microscopic appearance of the tissue is made out by taking a section of the brain extending through the cortex. In doing this it is seen that the tissue is arranged in such a way that distinct zones can be recog-

nized. It is common to refer to four distinct zones, which beginning at the surface and passing inward consist of:

(1) The molecular layer which is made up of nerve fibres running both inward and at right angles, kept together by the neuroglia and the branches from the nerve cells which are carried up from the other layers yet to be mentioned. It is said that certain peculiar cells are present in this layer, known as the cells of Cajal, which lie near the surface and are seen to be small, irregular in shape and size, and with processes that are short and run towards the surface. They are not always present, some claim only in the embryonic stage of human existence, but are of fairly common occurrences in the lower forms of life. Their function is unknown.

(2) A layer of small cells which are pyramidal in shape the apex pointing towards the surface and sending a single process upward which ends in the molecular layer. From the sides of the cell processes come off which intertwine with one another and with the cells adjacent. The true axis-cylinder process comes off from the base and becomes the axis-cylinder of the true nerve fibre, but may at times turn backwards toward the surface.

(3) Another layer of cells, in this case also pyramidal in shape but larger than those just referred to. The axis-cylinders in these cells are stronger and thicker, and always form a true axis-cylinder of a nerve fibre.

(4) A layer of irregular shaped cells. The apical process is wanting, but the lateral branches are present, as also the main branch which forms the axis-cylinder of one or more true nerve fibres. They are mostly polygonal in shape.

The rest of the substance consists of white matter bound together with neuroglia, which is present throughout the whole of the substance of the brain and is better developed at the inner surfaces, that is at the margins of the ventricles.

The cerebellum is the part of the brain substance which lies underneath the cerebrum and is connected to it by three pairs of peduncles — the superior, the inferior and the lateral. It is made up of white and grey matter also, the arrangement being such that on section there is a very fine arborescent appearance presented which has received the name, "arbor vitae," signifying the tree of life.

A microscopic examination of a section so prepared that the cortical area is included, shows that the grey matter is made up of three distinct zones or layers, the outer corresponding to the molecular layer of the cere-

brum. The second layer consisting of small cells, known as the cells of Purkinje and being characteristic of the cerebellum. These cells give off a main branch which is continuous with the nerve fibre and passes inwards into the substance of the white part of the cerebellum, while from the other end of the cell comes off the peculiar branching processes which give the characteristic appearance to the cell. They are flask shaped and are also known as the tadpole cell on account of their shape. Beneath this layer is the granular zone, which consists of very small cells some of them being neuroglia cells, others, nerve cells of varying sizes, but mainly of the multi-polar variety. The processes pass either into the molecular layer or simply remain mixed up with one another. The remainder of the substance of the cerebellum consists of white matter as described.

The medulla oblongata is the connecting part between the cerebellum and the spinal cord. The structure of the medulla oblongata depends upon the section which is considered, seeing that at different levels the relationship existing between the structure of which it is composed varies considerably. It is sufficient to say that the grey matter is internal and its distribution variable, depending upon the passing of the fibres from the one side to the other, or the different parts of which it is composed, and the level of the section.

The Spinal Cord is that part of the central nervous system which lies within the spinal canal, being continuous with the medulla oblongata. It does not extend the whole length of the spinal canal, but terminates as a cord and is continued as a mass of individual nerves, spoken of as the cauda equina. It consists of white and grey substance, the white being external and separated to a certain extent by an anterior median fissure and the posterior median septum, so that two distinct halves are recognized. The grey matter lies mainly in either half, but communicates with its neighbor half by the grey commissure. The grey matter approaches the surface in such a way that cornua or horns are distinguishable, these horns being spoken of as the anterior and posterior cornua; from them the spinal nerves emerge and form the anterior and posterior roots of the spinal nerves. The white matter of the cord is similar to the white matter already described, the fibres running either perpendicular or transverse, that is to say remaining in the one half throughout their length or else running part of the way in the one half, then passing to the other and running through it. The grey matter consists of multipolar nerve cells with axis-cylinders, some small nerve cells, the axis-cylinders of other nerve fibres, some of them from the white substance and some of them

from the posterior roots; all of these structures being bound together by the neuroglia. The multipolar cells are distributed in groups at the anterior cornua, the posterior cornua and in the lateral portions of the crescent. The smaller cells are distributed irregularly. It must be borne in mind that the cord is of some length and any description must be more or less qualified by the level at which the examination is made. The multipolar nerve cells are spoken of as the motor cells; the body of the cell is of considerable size and the processes coming from them are numerous and distributed extensively in the substance around. The main process forms the axis-cylinder of the nerve and becomes, after it has passed from the anterior cornua and received its medullary sheath, the nerve fibre. The other cells are smaller, with fewer and less branching processes which extend far into the substance, the axis-cylinder running in such a way that it forms an ascending and a descending fibre which ramifies in the white matter but terminates eventually in the grey matter as collateral fibrils. They are known as column cells when they follow the above course, but they sometimes pass through the commissure from the one side to the other, then they are known as the commissure cells.

The nerves have already been described as the cranial and the spinal; all that need be said about them further is that they originate as the names indicate, in the one case from the brain, in the other from the cord. Those from the cord coming from the anterior and posterior nerve roots or cornua of the cord. The anterior is smaller than the posterior, is motor in function; the posterior is larger and has developed in it a ganglion which lies in the intervertebral foramen and just external to the ganglion become fused together; that is, the anterior and posterior roots unite.

The Membranes of the Brain and Cord. — There are three distinct membranes recognized as forming the coverings to the central nervous system, although some look upon them as being divisions only of the one.

The deepest is the pia mater, which closely invests the surface passing into the sulci in the brain and is composed of fine connective tissue with a great number of small blood vessels, being in fact the vascular covering. It should be noted that at the sulci there would be a double layer on account of the reflection and this is also true of the cord where it dips into the anterior median fissure.

The arachnoid is the second or middle covering which invests the brain and is a smooth, transparent membrane, it lies in very close contact with the pia mater over the greater portion of the brain. Between these two

membranes there is more or less of a space which is called the sub-arachnoid space. The arachnoid and the pia mater are united together by a large number of fibrous strands or trabeculae, which extend from the inner surface of the arachnoid to the outer surface of the pia mater.

The dura mater is a thick, strong, fibrous membrane, consisting of elastic fibres running in connective tissue, the inner surface being covered with epithelial cells, the outer surface being closely adherent to the inner surface of the skull. In the spinal cord the inner layer corresponds to the dura mater, the outer forms the periosteal covering to the bone.

The nerves penetrate through the meninges and they are more or less continuous with the different connective tissue coverings of the nerve fiber.

The cerebro-spinal fluid is of a watery consistency, somewhat similar to lymph with some salts and albumen in solution.

The blood-vessels throughout the whole system are in the form of networks, being somewhat finer in the grey than in the white and are surrounded by endothelial cells, which form somewhat of a canal, the so-called "juice channel." The lymphatic spaces consist of the clefts or spaces between the membranes, which communicate with the juice channels in the nervous tissue. These different spaces communicate with one another and with the spaces in the peripheral nerves, and also with the nasal mucous membrane. There are a few small nerves distributed in the dura mater.

THE EYE.

The different parts associated with the sensation of sight are the eyeball, the optic nerves, and as accessories the eyelids, the lachrymal glands and ducts.

The ball of the eye is a globe with the diameters somewhat unequal, consisting of three coats, or layers, and the material within, which is of a fluid nature; but in addition there is the lens and the vitreous humor.

The outer layer is of a fibrous character and contains the cornea as a part of the membrane. On making a section through the corneal zone, the cornea is found to consist of several different parts; an outer layer of epithelium; an elastic layer; the substance proper, which is made up of fibres bound together with some cement substance and in which there are some corneal cells within the so-called cell-spaces; another elastic layer; and finally a layer of epithelium or perhaps more correctly termed endothelium. The remainder of the outer layer is made up of fibrous connective tissue with a very small quantity of elastic material, amongst the tissue

being some connective tissue cells. This portion is spoken of as the scleral part of the outer covering of the eye.

The middle coat is the vascular membrane of the eye and the blood vessels which it contains are divided into two distinct layers. The different parts of which it is composed are the choroid proper, the ciliary portion including the muscle, and the iris.

The choroid consists of connective tissue with pigment in the cells to which the color of the eye is due, usually dark in the human but variable in different forms of existence, the blood vessels being supported by this connective tissue. It extends as far towards the front of the eye as the level of the cornea, where it terminates as a series of small projections in a circle, these projections being the so-called ciliary processes which lie behind the iris. The structure of the choroid is an outer layer of connective tissue, beneath which are the blood vessels having the large plexus of vessels nearer the surface and the smaller, including the intricate network of capillaries beneath, the fine elastic membrane of Bruch and a fine layer of epithelium being placed deeper in such a way as to be between the middle and internal coats.

The ciliary region consists of the ciliary processes already mentioned and the ciliary muscle. The ciliary muscle consists of involuntary muscle fibres, which arise from the margin of the sclerotic close to the cornea, pass to the iris partly and partly to the ciliary processes, some fibres forming a circle which is spoken of as the circular ciliary muscle and is said to be extra well developed in cases where there is a hypermetropic condition of the eyesight.

The iris is the portion of the middle tunic which passes in front of the lens. It is attached to the choroid and the sclerotic by means of the ciliary muscles just mentioned. It is somewhat similar in structure to the choroid, being made up of fibres and pigmented cells (the pigment being variable in different individuals) with some muscle fibres and blood vessels. The muscle fibres are of the involuntary type and are arranged in such a way that some of the fibres form a sphincter or circular set while others form radiating strands from the center towards the periphery. The opening in the center forms the pupil. The outer surface is covered with a layer of simple squamous epithelium, the under surface with a fine layer of pigmented epithelium which is known as the "uvea" and continuous with the pigment layer in the retina. It should be noted that small nerve fibres are found in the choroid and the iris.

The inner tunic of the eye is the retina and is of considerable impor-

tance being referred to as the nervous layer or tunic. It is more complicated in its structure, being made up of eight different layers. It is a very fine membrane and covers the inner surface of the globe terminating at the margin of the ciliary processes, so far as naked-eye appearances go, but terminates in reality at the apices of the processes. It is translucent in life but after death becomes opaque. The inner surface has two marks plainly visible one at the center, the macula lutea or yellow spot, the other a little to the nasal side of the yellow spot the central disc or the optic pore, the place where the optic nerve enters the globe of the eye; it is the blind spot.

The different layers are: (1) the nerve fibres which are closely united with one another forming a network, consisting of the fibres of the optic nerve scattered out, they are now surrounded by a medullary sheath but consist entirely of the axis-cylinders. (2) Nerve cells of the multipolar type mainly but some of them are bi-polar the axis-cylinder process being continuous with the axis-cylinder of the fibre just mentioned. There may be simply one layer of these cells or several. (3) An inner granular layer, somewhat like the grey matter in the brain and cord. The fibres and cells are in relation to this layer and the whole area is granular. (4) The internal nuclear layer which is composed mainly of bi-polar nerve cells, the nuclei being large and granular. (5) The external granular layer which is thin and composed to a great extent by the branches from the cells of the internal nuclear layers with fibres from the rods and cones. (6) The outer nuclear layer which consists of cells and fibres with some material keeping them together. (7) The layer made up of the rods and the cones. They are placed side by side and distributed over the whole area of the retina with the exception of the yellow spot; the rods are more numerous than the cones and easily distinguished from them. This layer is a part of the neuro-epithelial structure of the eye. (8) The epithelium layer, consisting of hexagonal, pigmented, cells of epithelium, having a smooth surface in contact with the vitreous humor, but close to the rods and cones they form fine threads which extend between these rods and cones.

The vitreous humor consists of a fine membrane within which lies the peculiar substance having the viscid consistence, the whole lying within the eye in contact with the retina around but also with the lens in front.

The lens is the biconvex structure which lies in front of the vitreous and behind the iris. It is surrounded by a capsule which is transparent and elastic, the substance proper being the lens-fibres which are elongated

bodies with serrated edges some of which are nucleated. Between the capsule and the fibres anteriorly there are some cubical epithelial cells.

The eyelids are covered externally by skin, internally by mucous membrane (conjunctiva) between which lie some muscular and fibrous tissue. In the skin are some hairs and the usual sebaceous glands associated with them. In addition to that there are the Meibomian glands which are simply sebaceous glands opening along the margin of the eyelid.

The lachrymal glands are small racemose structures resembling the serous salivary glands, the ducts are numerous, open at the conjunctival surface and are covered by epithelium.

The blood supply to the eye is considerable and is conveyed to it by quite a number of arteries. The lymphatic system consists of several spaces and not the usual capillary arrangement. The nerve supply is quite free and has been referred to somewhat, in speaking of the coats of the eye.

THE EAR.

The different parts of the organ of hearing are the external, middle and internal ear, the first two being essentially accessories.

The external ear consists of the cartilaginous portion in the pinna and the external auditory canal, with the tissue covering it, and the tympanic membrane. The cartilage is of the yellow, elastic type. The external canal is covered with the reflection of the skin from the outer surface, within which we find the ceruminous glands. The glands are supposed to be similar to the coil glands in the skin; they differ from them somewhat in appearance, having a wider lumen and some granules of pigment in the cells with some fat drops in addition. The cerumen consists of pigment cells, oil globules and cells with fat in them; the function it performs is obscure; probably it, like the sweat, is constantly formed and coming off without much apparent cause, but in cases where the nerve force is abnormal then we have an excess of wax thrown out as a result of the abnormal condition just in the same way that we find an excess of sweat thrown off in cases where the nerve force becomes altered.

The tympanic membrane consists of a layer of fibrous and elastic tissue, with a covering on the outside similar to the covering of the walls of the canal internally with a reflection of the mucosa covering the cavity within. At the place where the malleus lies there is some cartilaginous tissue deposited of the hyaline type.

The vessels and nerves are similar to those in the skin except that in the tympanum an artery lies on one side of the malleus and the dis-

tribution of the capillaries is in radiating lines from these vessels. The vessels in the outer covering of the tympanum anastomose with those on the inner side.

The middle ear consists of the tympanic cavity and eustachian tube. The tympanum is a six sided cavity within the temporal bone. It is covered by a mucous coat which is intimately blended with the periosteum in the region. The mucous membrane is made up of fine connective tissue with a single layer of epithelium which is usually cubical but in some cases it is partly ciliated. The eustachian tube communicates between the tympanum and the pharynx; it is covered by a fibrous tissue stroma upon which there is a stratified layer of ciliated columnar epithelium with a few mucous glands. The blood vessels, in both of these regions, form deep and superficial capillary networks, the latter surrounding the glands when present. The lymph spaces are in the periosteum and the nerve distribution is very uncertain.

The internal ear is the most important and most complex. It is made up of an osseous portion which is simply a cavity in the petrous portion of the temporal bone, and a membranous portion which is essentially a membrane in the form of a tube lined with epithelium and floating within the osseous portion in a fluid medium known as the perilymph; in other words the membranous portion does not fill up the whole of the osseous. The membranous portion consists of these parts — the utricle, the three semicircular canals, the saccule and the canal of the cochlea. The first three of these structures consist of fibrous tissue, which is supported by a partial connection to the bone and by strands, allowing the fluid referred to, to encircle them and being within a covering of an epithelial membrane which is in the semicircular canals in some parts in small projections but in the others it is a ridge or a thickening with the cells of a columnar type from which the hair-like processes extend into the endolymph, and which are directly continuous with the axis-cylinder of a nerve fibre. The hairs in some of the parts of their distribution lie in a mucous-like mass in which are some calcareous particles, the so-called otoliths.

In order to understand the canal of the cochlea it is necessary to understand the bony cochlea within which the canal is formed. It is a tube coiled upon itself like a snail's shell and having within a plate of bone extending part of the way across the opening from the inner side but carried over to the outer by membrane in such a way that a triangular space is formed, leaving three different canals within the original canal. In this way a triangular space is formed which is the membranous cochlea

being bounded on the one side by the scala vestibuli and on the other by the scala tympani, it extends throughout the length of the cochlea and terminates in a blind apex and at the base is enclosed just at the fenestra rotunda.

The basilar membrane lies between the scala tympani and the membranous cochlea and upon it the structure spoken of as the organ of Corti is found. The organ consists (1) of the rods of Corti, which are two rows of striated fibres lying about the middle of the basilar membrane and arranged in such a way that the inner row overlaps the outer and thus leaving a space between, which has for its base the basilar membrane and its sides these two fibres. (2) Close to these fibres are elongated, stiff, cilia-like cells projecting into the endolymph. They are arranged in bundles, some of them external to, the others internal to, the fibres just mentioned as the rods of Corti, and constitute the external and internal hair-cells. These cells are probably in connection with the terminal ramifications of the auditory nerve in the same way that the olfactory nerves are in continuity with the specialized epithelial sensory cells, but in this case the connection can only be imagined, not proved. (3) A delicate membrane, the lamina reticularis, extends over the organ of Corti, with perforations for the small, hair-like process, it consists of a delicate structure and is superficial to a layer of ordinary epithelium.

The blood vessels of the cochlea are arranged in such a way that the scala vestibuli is surrounded by arteries, the scala tympani by veins, in this way no arterial pulsation mars the effect of sound waves. The other portions of the internal ear are supplied by the branches of the auditory and the stylomastoid artery. The lymph spaces within the cavity of the skull are in close connection with these spaces which contain the endolymph. The auditory nerve can be traced into the space formed by the rods of Corti and some think even to the terminal epithelial cells.

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